1988
MANITOBA
SWINE SEMINAR

FOCUS
on the
FEEDER BARN

February 2 & 3, 1988

Manitoba
Agriculture

88-04615/

AGENDA

Tuesday - February 2, 1988

Chairman:	Dr. M. Sheridan, Veterinary Practitioner, Steinbach, MB
9:15 a.m.	Coffee and Registration
10:00 a.m.	Lost Opportunities in the Feeder Barn (or Is a Pig's Room Worth More than its Company?) - Dr. J. Patience, Prairie Swine Centre, Saskatoon, SK
11:00 a.m.	Managing Feeder Pigs for Better Health - Dr. D. MacDougald, Swine Practitioner, Wellesley, ON
12:00 noon	LUNCH
1:30 p.m.	Good Husbandry Makes Dollars and $ense - Dr. P. Hemsworth, Animal Research Institute, Werribee, Australia
2:30 p.m.	COFFEE
3:00 p.m.	Pig Space versus Place - Dr. S. Baxter, Robert Gordon's Institute of Technology Aberdeen, Scotland
4:00 p.m.	ADJOURN
7:00 - 9:30 p.m.	Panel Discussion with Speakers and Informal Reception (Cash Bar)

Wednesday - February 3, 1988

Chairman:	D. Hodgkinson, Agricultural Engineer, Manitoba Agriculture, Winnipeg, MB
9:15 a.m.	Coffee and Registration
10:00 a.m.	Housing the Growing-Finishing Pig - Dr. S. Baxter, Robert Gordon's Institute of Technology Aberdeen, Scotland
11:00 a.m.	Handling and Welfare of the Growing-Finishing Pig - Temple Grandin, University of Illinois, Urbana, Illinois
12:00 noon	LUNCH
1:30 p.m.	Feeder Barn Ventilation - What do we Know? - Dr. E. Barber, University of Saskatchewan, Saskatoon, SK
2:30 p.m.	COFFEE
3:00 p.m.	Growth Promotion - What's In Store? - Dr. J. Patience, Prairie Swine Centre, Saskatoon, SK
4:00 p.m.	Adjournment and Informal Discussion

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Handling and Welfare of the Growing Finishing Pig	Pink Sheets
Feeder Barn Ventilation - What do we Know?	Green Sheets
Growth Promotion - What's In Store?	Yellow Sheets

LOST OPPORTUNITIES IN THE FEEDER BARN

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Introduction

Records
- -Accuracy
- -Days to market
- -Feed conversion

Nutrition
- -Feed wastage
- -Diet formulation
  - -Crude protein
  - -Essential amino acids
  - -Energy:lysine ratio
- -Opportunity feeds
- -Analyse
- -Feed separation

Labour
- -Preventative maintenance
- -Scheduled maintenance

Flexibility
- -Pig
- -Labour
- -Capital
- -Feed/water
- -Housing

Introduction

Despite the fact that over 60 percent of the cost of production resides in the feeder barn, in past years this area of the production cycle often received very little attention. The obvious problems in the breeding, gestation, lactation and weanling areas put the feeder barn at the bottom of the priority list of most producers. Recent improvements in housing design and management have helped to resolve some (but not all) of the problems in these areas. As a result, the feeder barn has been rediscovered as a profit centre that demands the same attention to detail that other phases of production require - and deserve.

What may separate the feeder barn from the other areas is the fact that the number of "details" appears to be much less than in gestation, lactation, etc. However, because so much of the cash on a farm flows through the feeder barn, the penalty for ignoring these details can be severe! The reality of 55 cent pork has forced us all to re-evalutate our total management system!

Records

The importance of good records - financial and production - is now well established. The computer has helped many of us monitor cash flow, animal flow and production in a very sophisticated manner. However, there is a note of caution.

Records from a computer are only as correct as the information keyed in and the accuracy of the program used to do the calculations. I would caution you all to try to understand how your computer program makes its calculations so that you know where all this information is coming from. I am not referring to the electronics of the computer, but rather to the program - the software in computer lingo - that converts raw data into the nice neat summaries. Often, the summaries make important assumptions that can influence how the data is to be interpreted. If you are unaware of these assumptions, you may misunderstand the information and make erroneous management decisions.

Compare your computer summaries with "real" data. For example, if the computer says you are weaning 21 pigs per sow per year and you have a herd of 100 sows, are you really weaning 2100 pigs per year? Little checks like this will give you greater confidence in the computer - and rightly so!

Some producers have not yet purchased computers, or do not yet use them for prodution records. A recent survey in Ontario, as part of the Ontario Pork Industry Improvement Program (OPIIP), demonstrated the importance of keeping records. Most people figure their pigs go to market in about 6 months or less. In the OPIIP survey the average days to market was 211.3! The average time in the feeder barn was 127.4 days! The average herd size in this survey was 77 sows. There is clearly an opportunity here to improve productivity and reduce expenses. However, few people keep track of days to market because it is not easily done on every pig. However, a fairly simple estimate can be determined.

IF the number of pigs in a barn is reasonably constant, you can estimate days to market by measuring the rate of inventory turnover (if the number of pigs in the barn fluctuates too much, the results will be misleading). This is relatively easy to do and the information generated is well worth it. To measure turnover, you must know the average number of pigs on the farm throughout the year and the number of pigs sold per year. Month-end inventories, averaged for the year, is a useful approach.

"Sales" should include not only hogs sold but any gilts raised in the barn as replacement breeding stock.

Example:

Average inventory = 965 hogs
Number pigs sold/year = 2097

Inventory turnover = 2097/965
= 2.17

Average days to market = 365/2.17
= 168

In view of recent surveys, no one should feel surprised to learn that their days to market is above 200 days. However, the experience of some commercial producers indicates that 165-170 days to 100 kg is a realistic management objective. Indeed, even better performance (150-155 days) appears possible with careful management, healthy stock, excellent diets ... and maybe just a bit of luck! If average days to market is too long, the following are most likely involved: health, diet (and water) quality, genetics and housing. Health and housing will be covered by other speakers. Diet will be discussed below. Genetics should not be a problem, given the availability of good quality breeding stock in this province.

Feed conversion in the feeder barn can also be estimated, if you know how much feed entered the barn during the year. This can be determined by measuring the feed inventory at the beginning of the year, adding all purchases and subtracting the year end inventory. Obviously, this calculation is much easier if you purchase all of your feed. The calculation can also be carried out for the total farm, if feed cannot be assigned to individual barns. The following example is for a feeder barn only.

Example:

Feed disappearance = 683.8 tonnes/year
X 2204 lb/tonne
= 1,507,185 lb/year

Amount of pork sold = 356,490 lb./year
(from marketing statements)

Liveweight sold = 356,490/.79
= 451,253
(79% dressing percent)

Conversion = 1,507,185/451,253
= 3.34

This calculation assumes fairly uniform flow of pigs through the barn. If this is not the case, the information could be badly skewed.

If feed conversion is too high, the most likely culprits will be wastage, poor diet quality and disease.

Good information on days to market and feed conversion will provide a very important basis for future management decisions.

Nutrition

Since feed makes up such a large portion of the cost of operating a feeder barn, nutrition, including feed composition, feeding management and feed handling, becomes a logical focus of attention.

Feed wastage is a constant problem in all feeder barns. You can leave the barn one day with well adjusted feeders only to return the next day to a mess of wastage. Thus, feeder adjustment is an on-going chore. It isn't very exciting, but it can save you a great deal of money. Adjusting feeders so that pigs have easy access to feed, but don't waste any is a daunting goal. But, it may save you more money than any other management change. Best of all, it won't cost you any money, unless you need to repair/replace feeders. If you assume that it costs $37 to feed a pig from 50 lb to market, than a 10% wastage problem costs almost $4 per pig. Where else can you save such an amount of money per pig?

When you go home, spread a little bit of feed onto the floor of one of your feeder barn pens. Once the pigs get over the novelty of it, drop another 6 lb. of feed onto the floor. Walk away and come back 30 minutes later. Chances are, you won't be able to see any feed on the floor, yet that 6 lb represents about 10 percent of the pigs' daily feed intake for that pen (assuming 10-12 pigs per pen)! The pigs won't have eaten the feed, merely trampled it into the floor. I've done this myself; believe me, it's a humbling experience. If you can't see wastage that amounts to about $4 per pig, adjusting feeders to prevent wastage takes on a whole new importance.

Having made these comments about feed wastage, be sure that feeders aren't adjusted so tightly that pigs have a difficult time feeding. One extreme is no better than the other.

Diet formulation is another area for potential savings. Most farm-mixed feeds are formulated on the basis of crude protein. For example, a grower diet might contain 16% crude protein. The use of "crude protein" has certain problems that you should be aware of. This does not mean that "crude protein" should not be used in diet formulation, just that you beware of its limitations.

All protein contains nitrogen. Crude protein is determined in the laboratory by measuring the amount of nitrogen in a feed or feedstuff and multiplying this by 6.25. The value 6.25 was selected since, on average, the protein of most feedstuffs contains 16% nitrogen. If the total protein (100%) contains 16% nitrogen, than if one knows how much nitrogen there is in a feed, one can work the other way and multiply the percent nitrogen by 6.25 to give the amount of protein present. Thus, a starter diet will contain about 2.88% nitrogen and thus about 18 percent protein. Since this measurement of protein is approximate, the value is called 'crude' protein. Unfortunately, not all protein contains 16% nitrogen.

Proteins are made up of individual amino acids, almost in the same way that a necklace is made up of individual beads. There are about 22 different amino acids present in most protein. The actual amount of nitrogen in a protein varies due to the relative proportion of the amino acids which make up the protein. Table 1 shows that the nitrogen content of individual amino acids varies from 7.7% to 32.3%. As illustrated in Table 2, the actual nitrogen factor varies among protein sources, even among those commonly used in swine diets. Thus, in the case of cereals such as barley or wheat, and in the case of protein sources like soybean meal, using 6.25 over-estimates the amount of protein present.

There is a very good reason for establishing one common nitrogen factor for all feeds and ingredients. First, when analyzing an unknown mixed diet which contains many sources of protein, individual factors cannot be used since the analyst won't know the contribution of each ingredient. Second, the amount of nitrogen in protein also varies <u>within</u> ingredients. This is because the proportion of amino acids varies, due to variety, weather and so on.

The use of crude protein has served us well in the past, and no doubt will continue to play an important role in the future. However, as we demand better performance from our pigs, we will probably need greater precision in formulating diets than "crude protein" can provide. Most of the protein sources used on the Prairies do not contain 16% nitrogen, but closer to 17.5%; the appropriate factor then is 5.7, not 6.25.

A much more serious concern, from a nutritional perspective, is that in 1988, we should be formulating diets on the basis of amino acids, not protein. Indeed, when we are formulating a diet for swine, performance is not affected by the amount of protein present, but rather by the amount of essential amino acids present. The essential amino acids for the pig are identified in Table 1. If the diet is deficient in one of these essential amino acids, the performance of the pig will be reduced, irrespective of the amount of protein present. Therefore, we must consider not only the amount of protein present, which is a rough estimate of the adequacy of the diet, but we must look at the essential amino

acids. Indeed, on diets based on the coarse grains, under most practical circumstances, we need only consider lysine, methionine and threonine. If these three are adequate in the diet, the other essential amino acids are almost certain to be adequate as well.

Table 3 illustrates the point. A diet based on barley and soybean meal was formulated to contain 16 percent protein. A second diet was formulated to also contain 16 percent protein, but in this case, both soybean meal and canola meal were used. When this is done, the lysine content of the diet will drop slightly. Depending on the performance of the pigs, this drop in lysine content may not bring about an observable change in the barn. If the lysine level in Diet #2 is adequate to support the performance level of the pigs, no change will be seen. However, now that many producers are investing in more elaborate housing systems and up-grading their health status, they are expecting better productivity; the drop in lysine between Diets #1 and #2 may be detected in these herds and further adjustments must be made.

Some would suggest increasing the lysine content of Diet #2 to make it equal to Diet #1, as has been done in Diet #3 (Table 3). However, since canola meal is lower in energy than soybean meal, diets containing this protein source will be lower in energy. This brings up the next point and that is the ratio of energy to amino acids. This ratio is very important. The pig is being fed to produce red meat, or muscle. The rate at which this is accomplished is directed by the amount of amino acids available to build muscle, and the amount of energy available to drive the whole system. Thus, for GROWING and FINISHING pigs, the energy:lysine ratio is as important as the actual amount of lysine and energy present in the diet (In younger pigs, the amount of energy in the diet is very important due to limitations in the capacity of the gut; in older pigs, with relatively greater gut capacity, this is <u>less</u> of a concern).

If the energy:lysine ratio is too great, a fat carcass will result because the pig will be receiving too much energy compared to amino acids. The excess energy will be deposited on the carcass as fat, not muscle. Muscle can only be formed from amino acids.

The answer is Diet #4 in Table 3. Here, the ratio of energy:lysine is the same as Diet #1. Thus, Diets #1 and #4 should provide equal performance. In high producing pigs, Diet #2 <u>might</u> reduce growth rate and carcass quality and Diet #3 is probably wasting lysine. I have to hedge a bit when saying this, because, as strange as it seems, in 1988 we do not really know how much energy needs to be in a grower-finisher diet, and we also don't know what energy:lysine ratio gives the best performance or the best carcass.

However, if the old stand-by barley-soybean meal diet can be considered as the standard (at least for the present

illustration), then these assumptions are correct. Also, since the barley-soybean diet is a common one, it serves to illustrate the point: when formulating diets, amino acids as well as crude protein needs to be considered, and if the energy content of the diet is changed, then the ratio of energy to amino acids should also be reviewed.

Table 4 provides another illustration that may be useful. Given the low price and poor markets for wheat, and the desire for better performance, wheat is now added to many swine diets. However, although wheat does contain more crude protein, the amount of lysine in wheat is essentially the same as that in barley. Thus, if one formulates a diet in which some of the barley is replaced by wheat and considers only crude protein, the result will be to lower the lysine content (Table 4). Worse still, wheat contains more energy than barley, so not only does lysine go down, but energy goes up; the ratio of energy to lysine is therefore widened. Carcass quality is almost certain to suffer. Indeed, a number of producers have recently complained about this since adding wheat to their grower diet.

Therefore, when formulating diets, and especially when changing the ingredients in your diets, be sure to consider amino acid content if you want to maximize performance. Attention to such detail will allow you to take advantage of opportunity feeds.

"Opportunity feeds" is a name given to feed ingredients that become available to the hog industry as a result of market conditions, crop quality, etc. Any basal ingredient that can be used in hog diets in place of of "normal" ingredients and which will reduce costs and increase profits is called an opportunity feed. Thus, frozen canola, sprouted grain, lentils, peas, liquid whey, triticale and a host of other feedstuffs might be used to advantage in a swine diet. The key is to keep abreast of these opportunities as they arise and move quickly on them; once they become a common practice, the price will be driven up and the "opportunity" will be lost.

There are some other areas to look at in terms of reducing feed costs. One is to analyse your diets to ensure that 1) they are not under-formulated and 2) they are not over-formulated. One is just as bad as the other. If your diets contain inadequate nutrients, the effects are rather predictable: slower growth, poorer grades and reduced feed conversion. If certain deficiencies exist, such as minerals or vitamins, health problems may develop.

If your feed contains excess nutrients, money is obviously being wasted. Strong candidates for excesses are the minerals and vitamins and possibly protein. When the price of hogs is 85 cents, one is more willing to pay for "insurance' in the form of extra vitamins or trace minerals than when the price is 55 cents. Check your diets and be sure they meet but do not exceed requirements.

Watch for feed separation. Table 5 summarizes the results of a feed analysis carried out on samples taken from three locations in a feed bin. This was supposed to be a pre-grower diet, but the variation was so great that pigs receiving feed from this bin would be getting quite a different diet as it emptied.

Labour

The introduction of feed augers, liquid manure systems and animal loading chutes has removed much of the "grunt" work from the hog barn. However, the old adage of "work smart, not hard" still applies.

For example, preventative maintenance is not a common practice, but it should be. At the Prairie Swine Centre, we find that last minute repairs cost us as much as 40% more than scheduled repairs, just because we don't have the opportunity to comparative price. When it's -40°C and the heat exchanger breaks down, you often have to accept solutions that would otherwise be untenable.

Scheduled maintenance also ensures that jobs get done in the slack times of the year. It makes better use of labour and makes life much more pleasant in general.

Flexibility

When successful businesses are featured in books, magazines, or business school projects, one common feature is their flexibility. The same applies to successful farmers. Very little in our world - other than death and taxes - are cast in concrete. Remaining flexible allows the manager to take advantage of new opportunities; it does not mean being reckless, nor does it mean jumping on every new fad that comes along. It does mean looking at all aspects of the business and contemplating new approaches. Figure 1 illustrates the main inputs into pork production: the pig, labour, capital, feed/water and housing.

If we are looking for ways to save money, we have to look at all of these inputs and determine if alternatives exist. Is the existing feeding program the most economical one? Is the current breeding or health program maximizing your management skills. Should some of the loans be renegotiated or refinanced?

The price of pork has fallen from 90 cents to 55 cents in a matter of a few months. How many of us have stopped to consider the significance of this change in terms of how we feed and manage our pigs? We are fortunate that feed prices and interest rates are relatively low, because if they were higher, the impact of low prices would be magnified, obviously.

With the price of pork so low, the value of a few extra index points is greatly reduced. Thus, management efforts to raise index points must be reviewed. The difference between a 100 index pig and a 102 index pig is now only $1.96 (225 lb liveweight, 79% dressing percent), compared to $3.20 last summer. I have personally never agreed with floor feeding to boost grades, but if that's your pleasure, maybe now is a time to reconsider. The personal gratification of a high indexing herd may in fact be a very expensive proposition. Floor feeding, which also generally means limit feeding, reduces growth rate. The extent will depend on how much the intake of the pig is restricted. Floor feeding generally, but not always, increases carcass grades.

A system of feeding to scale offers considerable benefits in terms of carcass grades and feed efficiency. However, the current situation with low feed costs and low hog prices would minimize the benefits of this approach.

The selection of appropriate marketing weights could be another response to the market. Since feed is relatively inexpensive and interest rates low, the cost of a few extra pounds on each pig is as low now as it might ever be. Also, as mentioned above, the cost of losing a few index points is lower, and the overall balance may favour slightly heavier pigs. However, specific information on this subject is surprisingly lacking. A research project at the Prairie Swine Centre (and 3 co-operating farms), funded by the Saskatchewan Pork Producers Marketing Board and New Life Feeds is intended to answer this very question. The results should be available later this summer.

PORK PRODUCTION - THE TOTAL PICTURE

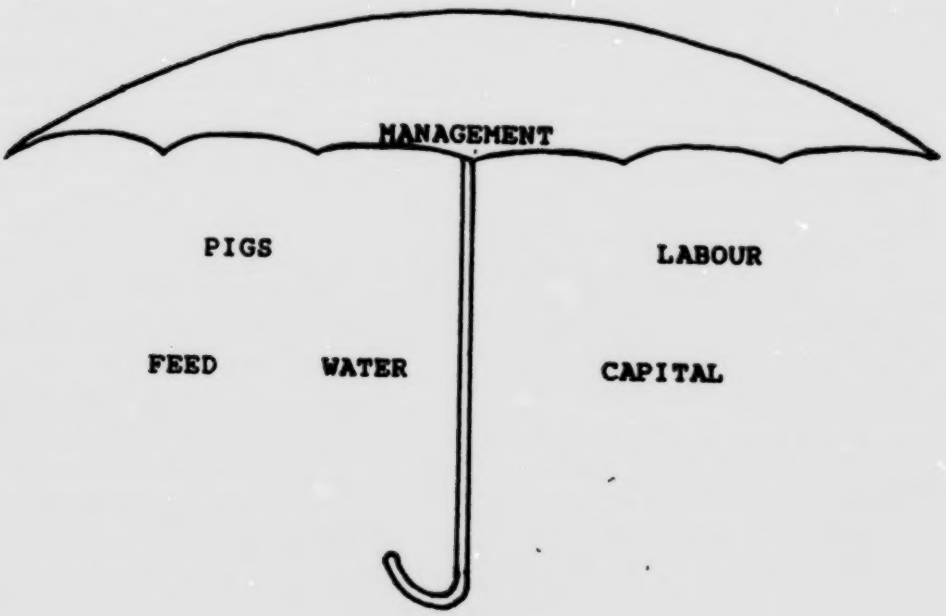


TABLE 1 AMINO ACID NITROGEN CONTENT

Amino Acid	% Nitrogen	Amino Acid	% Nitrogen
Methionine*	9.4	Cysteine	11.6
Lysine*	19.2	Tryptophan*	13.7
Phenylalanine*	8.5	Leucine*	10.7
Isoleucine*	10.7	Threonine*	11.8
Valine*	12.0	Histidine*	27.1
Arginine*	32.2	Glycine	18.7
Asparagine	21.2	Aspartic Acid	10.5
Serine	13.3	Glutamine	19.2
Glutamic Acid	9.5	Proline	12.2
Alanine	15.7	Tyrosine	7.7

* Essential in the diet of the pig

TABLE 2 PROTEIN CONTENT OF FEEDSTUFFS

Feedstuff	Nitrogen Content		True	Crude Protein	
	Protein	Feed	Factor	N X 6.25	N X Factor
	%	%		%	%
Barley	17.2	1.68	5.83	10.5	9.8
Canola meal	18.1	5.76	5.53	36.0	31.9
Corn	16.0	1.54	6.25	9.6	9.6
Flaxseed meal	18.9	5.82	5.30	36.4	30.8
Milk	15.8	0.53	6.38	3.3	3.4
Oats	17.1	1.68	5.83	10.5	9.9
Soybean meal	17.5	7.60	5.71	47.5	43.4
Wheat	17.2	2.06	5.83	12.9	12.0
Wheat bran	15.8	2.45	6.31	15.3	15.5

TABLE 3 FORMULATING DIETS TO EQUAL LYSINE CONTENT

	Diet No.			
	1	2	3	4
Ingredients, %				
Barley	80.8	78.5	72.3	74.0
Soybean-47	16.2	9.2	9.2	9.2
Canola	-	9.2	15.5	13.8
Premix	3.0	3.0	3.0	3.0
Nutrients, %				
Met. Energy	2880	2820	2810	2815
Protein	16.0	16.0	17.7	17.2
Lysine-avail.	.84	.77	.84	.82

Diet No. 1: Typical diet
2: Formulated to contain same amount of crude protein as Diet #1, but using soybean and canola meals in a 1:1 ratio by weight
3: Same as Diet #2, except formulated to contain the same amount of lysine as the Diet #1
4: Same as Diet #2 except formulated to contain the same energy:lysine ratio as Diet #1

TABLE 4 USING WHEAT IN GROWER DIETS

	Diets	
	1	2
Ingredients, %		
Barley	80.1	52.6
Wheat	-	30.0
Soybean meal	13.9	11.4
Canola meal	3.0	3.0
Premix	3.0	3.0
Nutrients, %		
Met. Energy	2860	2950
Protein	16	16
Lysine	.83	.75
Energy/lysine ratio	345	393

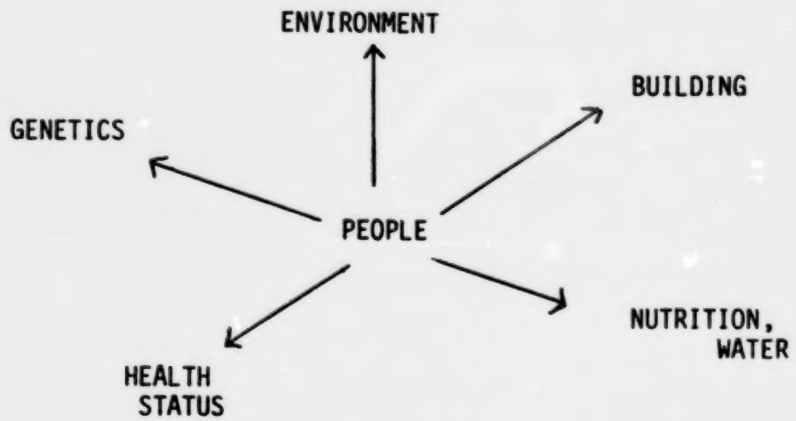
TABLE 5 AN EXAMPLE OF FEED SEPARATION

Nutrient	Beginning	Middle	End
Protein, %	17.6	17.4	15.7
Crude Fibre, %	3.8	4.2	9.0
Calcium, %	1.09	.99	.74
Phosphorus, %	.95	.85	.65
Salt, %	.74	.71	.61
Copper, ppm	23	20	20
Iron, ppm	310	200	200
Manganese, ppm	50	40	40
Zinc, ppm	260	140	140

Feed samples taken from the beginning, middle and end of the batch of feed as it was removed from the bin

MANAGING FEEDER PIGS FOR BETTER HEALTH

To qualify and improve on the effects of disease on finishing pigs, one has to maintain an overview of the interactions between the pig and all other factors affecting its well being. The basics of pig farming can be thought of in the following schematic:



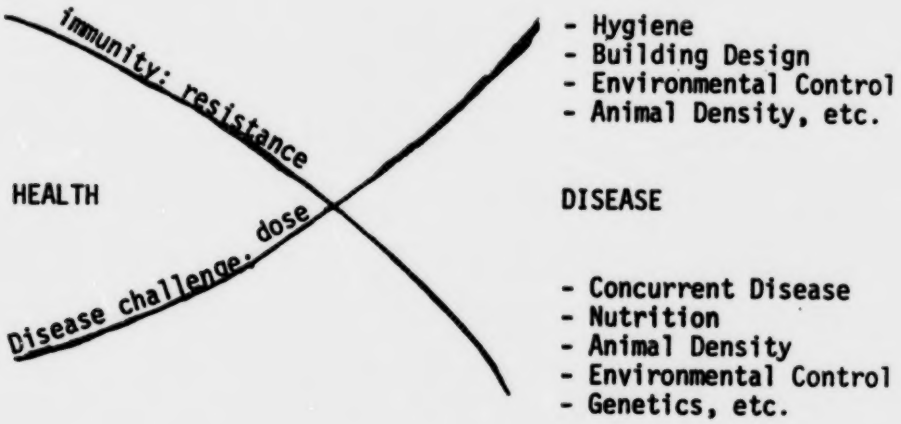
People remain the most important factor in the complex, high management job of raising pigs, and are the key for the remaining factors to work well. For example:

- Adjustment of environmental controls in response to changing weather and the pigs' comfort zone.
- Keeping control of pig flow, stocking density, projected numbers, and knowing what alterations of these parameters do to throughput.
- Monitoring of feed formulation and analysis, as well as maintaining and monitoring the feed delivery system.

- Maximizing cost effective genetic progress.
- Realizing the complex nature of health status and its constantly changing pattern in a herd.

"Why are animals sick?" Simple enough question, but one requiring a complex answer, as well as a basic understanding of health:disease balance.

The graph below depicts a health:disease model and shows some factors involved in creating a balanced healthy animal population. This basic understanding can be applied to any species including man and any disease or other stress related ailment.



So in answer to the above question, it is clear that most farms have many diseases in their herd, BUT if most management factors are in place then disease does not express itself or have any impact on production or profitability.

If the "dose" of disease goes up because of poor sanitation or lack of disinfection, then disease may overcome resistance or immunity. Disease challenge, as depicted on the graph, can increase for many other reasons, including building design, manure handling facilities, feeding equipment, ventilation system and control, animal density and many other management related factors.

What if the dose of disease has not changed, but your animals are less resistant? The health balance of the herd shifts to the right, and this can happen because of many factors as well. These factors include a balanced palatable ration, genetics, animal density or competition factors, concurrent diseases, environmental control, and the list goes on and on.

Farmers are faced with unbalanced health situations all the time. For the short term, identification of the disease with selective treatment may be necessary for the individual animal, as well as reducing the disease dose to the rest of the herd.

But, medium and long term plans have to point toward identifying the underlying reasons leading to an unhealthy balance. There may be only one organism that causes a specific disease, but there is a complexity of factors predisposing to that disease. Eliminating the stress factors one by one will allow you to shift your health balance toward the left of the graph, and even with minor changes in management input the herd isn't thrown into a disease situation.

* * * * *

The following is a case study to highlight the multi-factorial aspects of the influence of health on conversion, consumption, and profitability of finishing pigs.

This case is unusual because one owner has two farms (A & B) which have the same genetics, feed, and management direction; but different building design and health status.

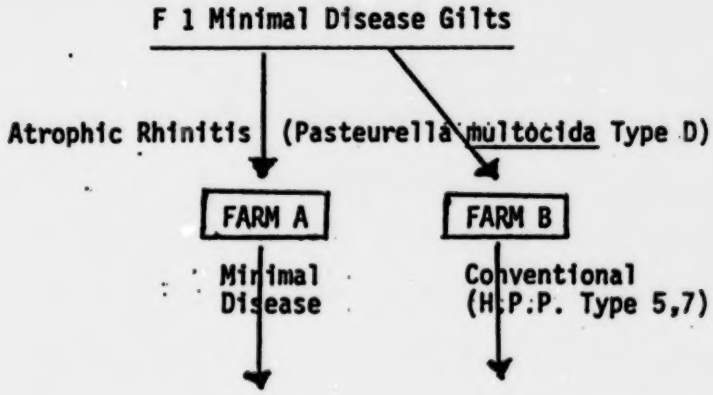
These two herds are supplied with F1 minimal-disease gilts from a breeding herd that broke with a severe atrophic rhinitis problem.

The clinical expression was delayed in the commercial minimal-disease herd (Farm A) for six months. The conventional status herd (Farm B) showed the clinical disease as soon as the carrier F1 gilts entered the barn. Farm B is a conventional health status herd that is positive for HPP type 5 and 7.

These two farms have separate feeder barns with Farm A documenting finishing performance before and after the atrophic rhinitis break. There was no change in performance, and over 50% of the pigs on both farms showed severe clinical signs at the height of the disease outbreak.

See Chart 1

Chart 1



	Feeder Barn A	Feeder Barn B	Change	
Weight Gain	157lb.(59-216)	"	-	
Consumption/Day	4.6 lb.	4.5 lb.	- 2%	
Average Daily Gain	1.7 lb.	1.51 lb.	-11%	
Days to Market	92	104	+13%	
F.C.	2.73	2.9	+ 6%	
Turns/Yr.	3.3	2.8	- 15%	
Mortality	.4%	4.8%	+ !	
Cost/lb. Gain	27¢	29¢	+ 7%	
Feed Cost/pig	$42.90	$45.50	+ 6%	(2.60/pig)
Barn Floor Space/pig	7.6 (solid floor)	7.2 (partial slatted)		
Pigs/air space	210	200		
Pigs/pen	11	20		

The conclusions are:

1. Atrophic rhinitis in the presence of the variables on these two farms had negligible effect on performance at the grower/finishing level.
2. There may be some argument about floor space and pigs per pen affecting the difference in performance between Farm A and B; however, the level of disease and this is specifically pneumonia, was a significant factor based on morbidity, mortality, and treatment levels.
3. Health made negligible difference on feed consumption per pig.
4. The largest economic loss was the decrease in average daily gain.

- Average Inventory = 210 x 3.3 turns/yr. = 693 pigs/yr.
  Less 15% (turns/yr.) = 589 pigs/yr.
  104 pigs

- Same feed costs
  ∴ Weaner pig value = $ 65
  Feed Costs = $ 43
  $108
- Feeder pig value = $162
  Margin = $ 54 x 104 pigs
- Lost potential profit = $5600

The difference in feed conversion for this same barn/yr. would be: 693 pigs x $2.60 feed cost/pig = $1800

5. Health resulted in minimal economic loss due to consumption and conversion, but had a major economic impact due to decreased throughput.

   This is based on limited feeder barn space resulting in weaner pig sales as the only option for slower growth.

6. Scientists want to define the variables and study the parts separately. Production specialists realize the whole has to be looked at as well as the parts because of the interdependence of known and unknown factors.

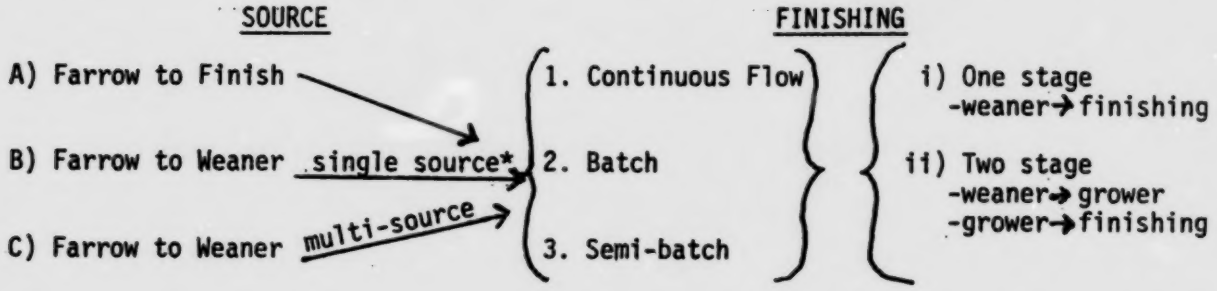
   Health and disease are not static and the expression or importance varies with the changing variables. The goal is to set priorities for weak areas of production or profitability and work toward a realizable target.

* * * * *

The quality of pig entering the finishing barn influences performance. Uniformity and growth potential, health, and size are essential to achieve good throughput and to minimize shipping time/pen.

Weaner pig problems and performance will therefore influence what is happening at the finishing end. Obviously the finishing system dictates what, if anything, can be done.

The various combinations of finishing are shown below:



* may or may not have the same health status as sow herd depending on:

a) origin of finishing stock

b) herd security, location to other pig herds

c) transportation security

Source is critical because health:disease is not static and constant changes in pathogens and/or susceptibility to existing pathogen challenge will cause continuing clinical disease with associated increased treatment, mortality, and performance costs.

The ideal is one single source or maintaining the closed herd concept from farrowing to finishing (farrow-weaner⟶finishing: or farrow-finishing)

If multi sources of unknown health status are used to co-mingle a continuous flow finishing barn the results are constant Hemophilus pleuropneumoniae, Swine Dysentery, and other problems.

One large U.S. farm broke down their enterprise to source type and compared the finishing mortality based on all-in all-out finishing barns.

The mortality rates to system are presented below:

SOURCE	HEALTH STATUS	MORTALITY RATE
One Source	Minimal Disease	.7%
Two + Sources	From same pyramid equivalent health status	2.1%
Multi Source	Co-mingled unknown health status	7.3%

A continuous flow finishing barn from any of the three different sources has been the common system but any company that moves a large number of weaner pigs is going to the complete batch system. This system is based on all-in all-out rooms or barns with a standard fill - empty - clean cycle. This can also be broken into a grower and finisher section, although not as common.

The benefits are obvious for a complete batch system:

1. Hygiene
2. Disease challenge

} - equates ↑ performance → throughput

3. Setting environment and nutrition to the pig's needs.
4. Records - with a definite start and finish

A semi-batch system will become more common as a compromise for small to medium sized farms. Continuous flow finishing barns will be compartmentalized to reduce number of pigs/air space and have less variation in size of pig/air space, but they will not be run as a batch system. Up to half the room will be empty at a time however, and this will allow for better cleaning and reduce the pathogen challenge because of reduced pigs/room.

Time after time I see the results of hygiene, or lack of it, in the finishing barn. Estimates of 1 - 2 weeks longer through the unwashed finishing phase are realistic depending of course on floor types and feeding system.

Growth promotant studies back up the importance of hygiene. One of the mechanisms of action of growth promotants is suppressing microorganism in the intestinal tract that are responsible for sub-clinical or non-specific diseases.

If the environment is ideal, then antibiotics are not needed for this function. Hay's study on the effect of environmental cleanliness on growth promotant response substantiates this direction.

Effects of Environmental Cleanliness on
Young Pigs' Responses to Antibiotics

	Control	Antibiotics	Improvement (%)
Gain (lb)			
Clean Building	17.8	22.9	28
Dirty Building	10.6	16.5	55
Feed/Gain			
Clean Building	1.90	1.74	8
Dirty Building	2.89	2.05	29

* * * * *

Any discussion of health control in finishing pigs needs to address the issue of drug use and abuse.

I recently read a headline in our local paper: "Livestock antibiotics linked to human ills."

This is another study providing more proof that widespread usage of antibiotics in livestock may lead to drug-resistant strains of bacteria in humans.

Anyone remotely connected with the livestock industry knows the implications of these findings -- more negative press on meat in diets. People in the livestock industry do not need this, but have no one to blame but themselves.

Drug companies and other groups have debated the above point for years, but it does not take a genius to know it is a self-serving argument based on economics, rather than reason.

A good example is a new drug that is used routinely in a herd will at some point lose its effectiveness.

Resistance transfer between bacteria is an accepted fact.

Recently I have seen two cases of tetracycline added to finishing pig rations with no thought to withdrawal period before slaughter and no prescription.

If I see two cases in one month, looking at a small number of well-run herds, what is happening across the rest of Ontario and Canadian farms? The argument that antibiotics in finishing pig rations produce better quality meat and lower prices is just not true for many farms.

I can confidently compare any farm that can produce pork without the benefit of antibiotics in the grower and finishing rations to one that uses them, and see which is better off productively and profitably.

In all fairness, there are some situations that warrant feed medication but it should be strategic for a specific growing phase, and should be viewed as a stopgap measure while the underlying causes are addressed.

The meat industry should have the same strict regulations that now govern drug residues in milk.

I once thought producer and agri-service education was all that would be required to see improvement in the drug use and abuse area; but it seems it will take restrictive legislation and tough penalties.

If our society has to be beaten over the head to stop drinking and driving, then it certainly will not stop livestock drug abuse without the threat of financial loss.

All farmers make the final decision if antibiotics are added to their ration. They must make sure they know what the levels are, what withdrawal is necessary, and if there is an actual need.

* * * * *

Roundworms are a good indicator of finishing barn hygiene. In fact the only situation where there is a significant roundworm problem in the finishing barn, if pigs are entering with no or minimal infection, is in a continuous flow unwashed facility.

Intestinal worms or parasites have negligible impact on productivity in well-managed herds.

The two intestinal worms of any concern in Ontario are Oesophagostomum dentatum (nodular worm) and Ascaris suum (round worm).

The nodular worm, which is 10 to 20 mm long, has a life cycle of 3 - 4 weeks. After the egg is passed, it takes 3 - 6 days to molt or hatch to the

infective stage, which is a free living larval form.

This means it has no protective coating and is susceptible to environmental factors. This larval stage, which is called L3, has high moisture requirements and an optimal temperature range of 10 to 25^{0} C. Any temperature outside this range, or drying conditions will kill it.

The L3, once ingested by a pig, develops rapidly into an adult in the large intestine and passes eggs within three weeks.

No age immunity develops with this parasite, and since the larval stage is very susceptible, the main reservoir of infection is the adult sow.

The number of eggs shed increases through gestation and peaks during lactation.

If basic sanitation is practised through the farrowing room, it is easy to prevent significant infection in nursing piglets.

The concern about this parasite is possible reproductive effects in the heavily-parasitized sow. These effects include decreased gestation weight gain, decreased birth weights, and poor weaning weights.

This type of parasitized sow herd should be rare but it does give some credence to the practise of deworming sows 1 - 2 weeks before farrowing. This should be done in the dry sow area.

There is no evidence that a moderate nodular worm challenge to the finishing pig has any affect on average daily gain and feed conversion.

The roundworm is the more significant parasite because it can decrease average daily gain in the growing pig. The mature roundworm is 1 - 2 feet long and lives for 6 - 12 months in the pig, shedding up to 1,000,000 eggs per day.

The life cycle is quite a bit different with the egg taking 2 - 8 weeks to molt to the infective stage L2, which has a protective shell. This makes L2 very resistant to environmental factors and it can live for up to ten years waiting to infect a pig.

Once ingested, the larval stage migrates through the small intestinal wall, liver (forming white spots), lungs, and back to the small intestine, where the adult form develops and starts producing eggs in 5 - 8 weeks.

The development of L2 is dependent on moisture and a higher temperature with the range from 15 - 35^{0} C., but optimal at 30^{0} C. This explains the seasonal pattern of summer increase in roundworm problems.

The main damage to the pig is presumed to be as the larvae migrate through the tissues of the pig.

Immunity does develop, producing a limiting action by the body on parasite load. The mature sow will usually carry only 3 - 5 worms maximum, with many having none. That is why it is so disappointing when the barn is not awash in long white worms after sows are dewormed.

Environmental contamination is the key for parasite load, with transmission primarily from infected pen to pig, and back again.

Sanitation is the key for control. There is rarely direct transmission from the sow to the piglet because of the long development stage to L2. If facilities are washed down and kept clean and dry, there will not be a roundworm problem.

The main areas of concern are unwashed, continuous flow areas such as weaner or finishing barns.

I question the cost effectiveness of depending on dewormers at this stage because roundworm eggs, as mentioned, are a good indicator of general hygiene. If they are present, what other pathogens are there to take the edge off gain?

Experimentally, average daily gain can be decreased by 10 - 30% with a heavy challenge of roundworm larvae. However, in a normal sub clinical state, decreased performance would range from 0 - 5%, depending on challenge level and overall health of the pig.

Fecal samples show the egg-producing worms at the time of sampling and are a very rough estimate of worm load. The long life cycle of the roundworm has to be kept in mind when analyzing fecal sample results. Composite samples from sows and feeder pigs can give clues as to parasite load and the effectiveness of the sanitation program.

Liver white spots can be seen at post mortem or slaughter check, and give some clues as to the presence of roundworms, but again are only an indicator of infection.

The usual recommendation is to deworm sows twice a year, or 1 - 2 weeks pre-farrowing using a broad spectrum dewormer or Ivomec depending on mange status of the herd.

Monitor infection in feeder pigs by fecal analysis and slaughter checks, and if there is a problem, deworming younger pigs may be necessary, but longer term the emphasis has to be on why there was a breakdown of hygiene.

* * * * *

The floor space allocation per pig is very important in dictating pig performance (Table 1 & 2) and behavior. These trials show clearly, as

floor space/pig is decreased, daily feed intake and thus daily gain decrease. The key factor is to identify at what floor space/pig maximizes the amount of pork produced/year. Arriving at that figure is one of the most important criteria for feeder barn performance because many other aspects of pig management are not limiting performance once they are too crowded. Put pigs in the finishing barn at different densities and measure throughput and find out what the optimal number is for your barn. This figure may be different for summer and winter.

There is also a direct correlation between severity of pneumonia and floor space (Table 3) and type of finishing system (Table 4).

Lindqvist (1974) found that pigs have a lower incidence of pneumonia where:

1) Less than 500 pigs occupied a section or building
2) $> 3m^3$ (82 cubic feet) volume of space/pig was allowed
3) $> 0.7m^2$ (7.5 sq.ft.) per pig floor area was allowed

Table 5 gives what the normal target and what the best do from birth to market. Also included in this table is the normal and best on feed efficiency, mortality, and culling.

Figure 1 is a scatter plot distribution of the normal growth rate of pigs and Figure 2 is the distribution of the growth rate of pigs affected by a poor finishing barn performance for which the reasons are many.

* * * * *

"The sick are the greatest danger for the healthy; it is not from the strongest that harm comes to the strong, but from the weakest."

All intensive pig farmers must understand this basic concept, and realize that a few sick animals can seriously disrupt the health balance in a herd, which may lead to a herd disease problem.

The attitude among many people is to forget the whole idea of a sick pen because in reality it is a "death pen". This concept and attitude is very callous toward the humane handling of pigs, and there is also lost profitability.

It is of more than passing interest to note that "recovery" is not listed in the medical dictionary, but of course "sick" is.

Recover: to regain health after sickness; to grow well again.

Intensive livestock producers need to think of recovery pens. Most of the direction on food-producing farms is herd management to prevent problems, but the intensification of these farms dictates that some individual animals will be unable to handle the stress level and will get sick.

Recognition of these sick pigs requires time to observe various things such as behavior, breathing, appearance, manure, appetite, growth, and temperature.

Once a stressed pig is identified, treatment should be broken down to nursing requirements and therapeutic requirements.

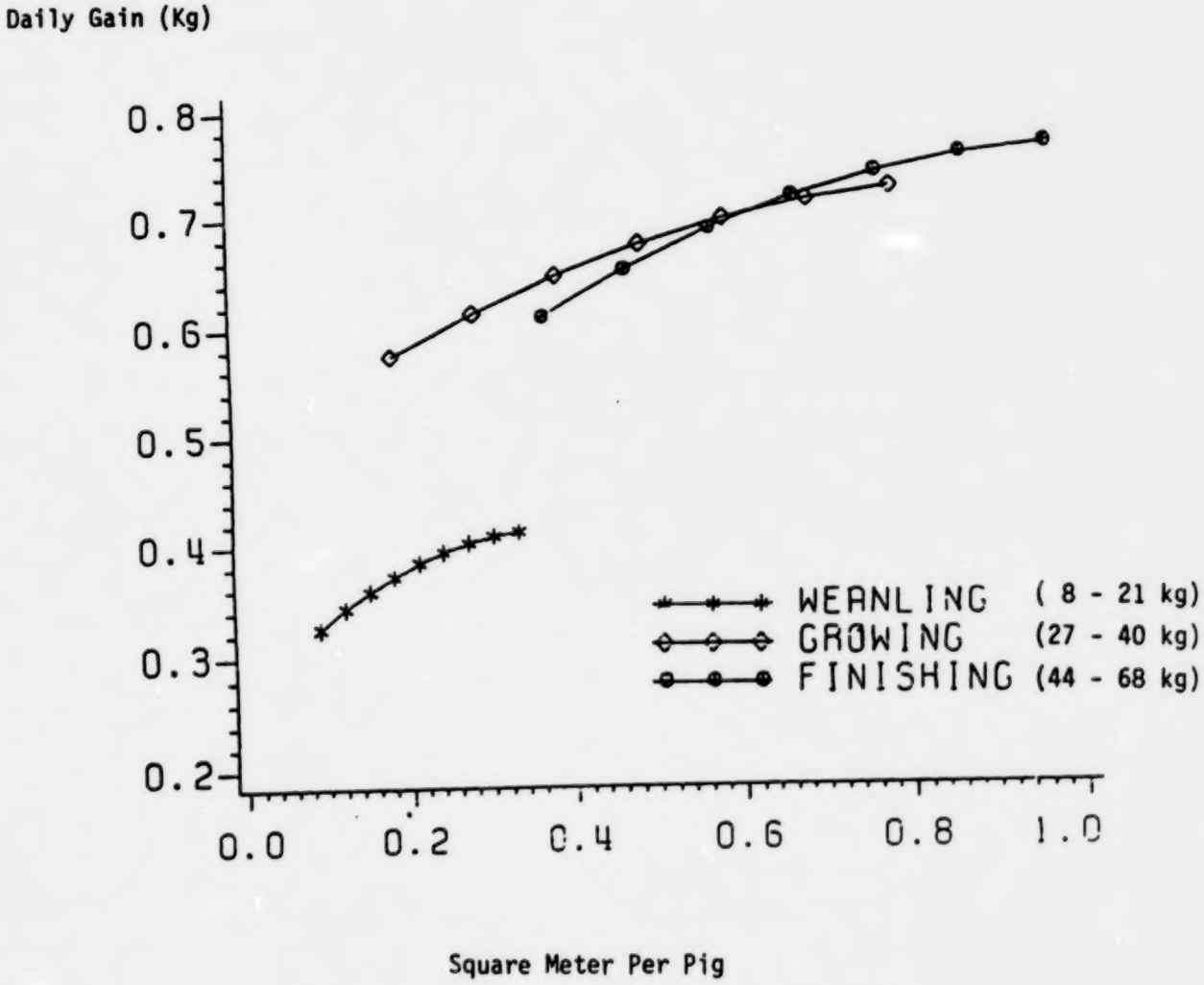
Nursing requirements of a stressed pig in all but the mildest cases, means removing that pig immediately to a recovery pen. The pen should be small with lots of room for individual animals. Solid flooring with bedding is necessary and added heat may be required. Easy access to food and water is common sense and these pigs may require a higher level of nutrition. Electrolytes through the water will help.

Additional therapy will depend on diagnosis of individual animal problems.

The recovery pen will serve its purpose when the pig is introduced into a new pen of smaller pigs, and we have fulfilled some ethical, humane, and economic aspects of pig farming.

TABLE 1

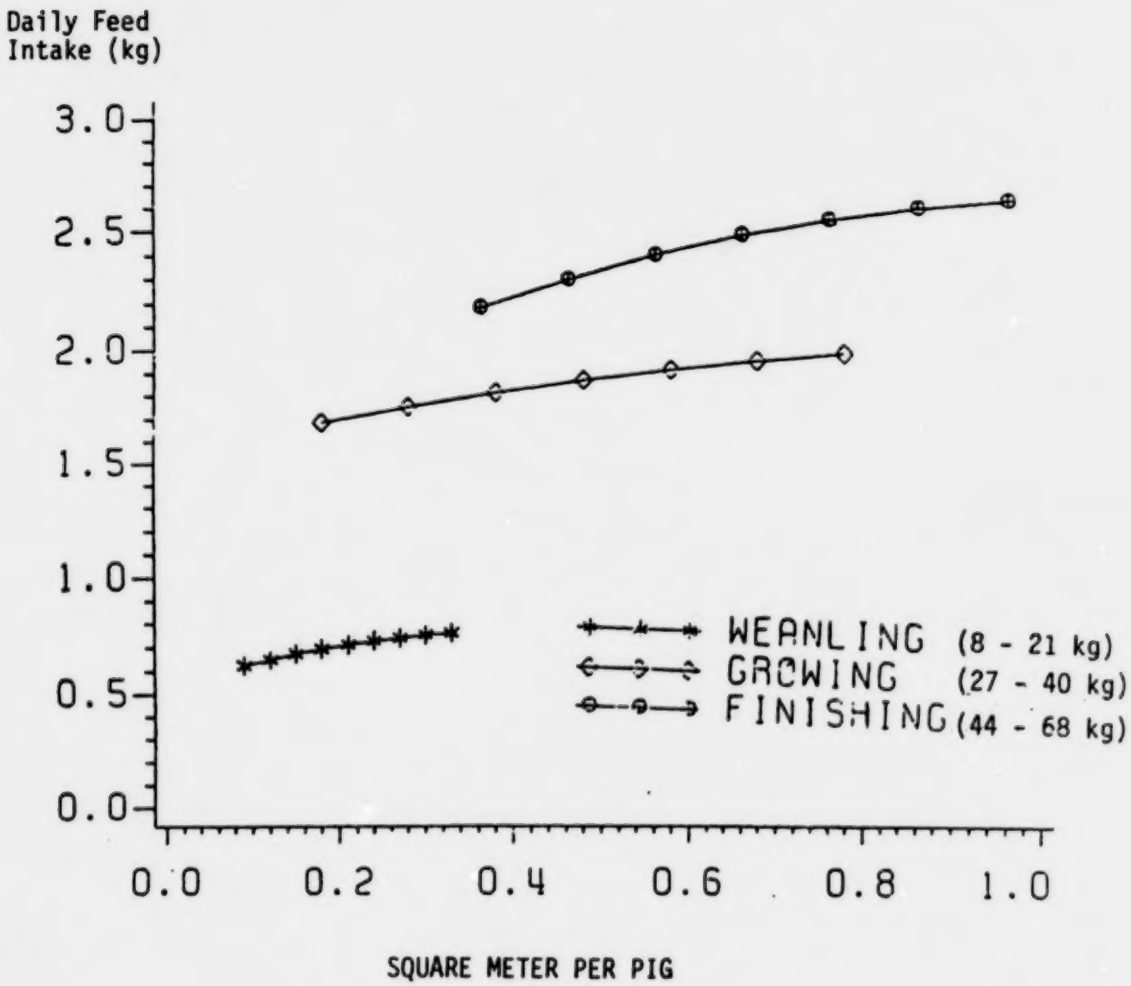
FLOOR SPACE PER PIG IN RELATION TO DAILY GAIN



Dr. Peter English
Aberdeen

TABLE 2

FLOOR SPACE PER PIG IN RELATION TO DAILY FEED INTAKE



Dr. Peter English
Aberdeen

TABLE 3

Environmental Factor	Periods	No of Herds	No of growing Pigs	Incidence of Pneumonia (%)	
				Period (1)	Period (2)
Floor space/pig $<0.5\ m^2$)					
)	1	9	2183	11.9	
Air volume/pig $<3.0\ m^3$)	2	9	1659		21.5
Floor space/pig $>0.5\ m^2$)					
)	1	4	590	2.4*	
Air volume/pig $>3\ m^3$)	2	4	1070		5.0*

Period 1 = 8 weeks: Period 2 = 5 weeks.
*Highly significant = $0.001 > P$

P. Thomas
ADAS, U.K. 1984

TABLE 4

	Periods	No of Herds	No of Pigs Slaughtered	Incidence of Pneumonia (%) Period (1)	Period (2)
All in - All out	1	7	2118	3.2	
	2	6	898		8.0
Continuous throughput	1	29	7614	11.1	
	2	28	5433		21.9
Solid manure	1	19	3873	7.6	
	2	19	3301		15.8
Liquid manure	1	37	10305	10.6	
	2	32	7461		22.4

P. Thomas
ADAS, U.K. 1984

TABLE 5

WEIGHT GAIN
FROM BIRTH TO MARKET

AGE	NORMAL TARGET		BEST	
4 Wk. (29 Days)	15 lb.		18 lb.	
		.75 adg.		1.0 adg.
8 Wk. (56 Days)	36 lb.		46 lb.	
		1.0 adg.		1.6 adg.
12 Wk. (84 Days)	75 lb.		90 lb.	
				2.1 adg.
21 Wk. (147 Days)	-		220 lb.	
		1.5 adg.		
26 Wk. (182 Days)	220 lb.		-	

FINISHING

Feed Efficiency	3.2	2.7
Perceht Cull pigs	2.0	< 1%
Percent Mortality	2.0	< 1%

Figure 1

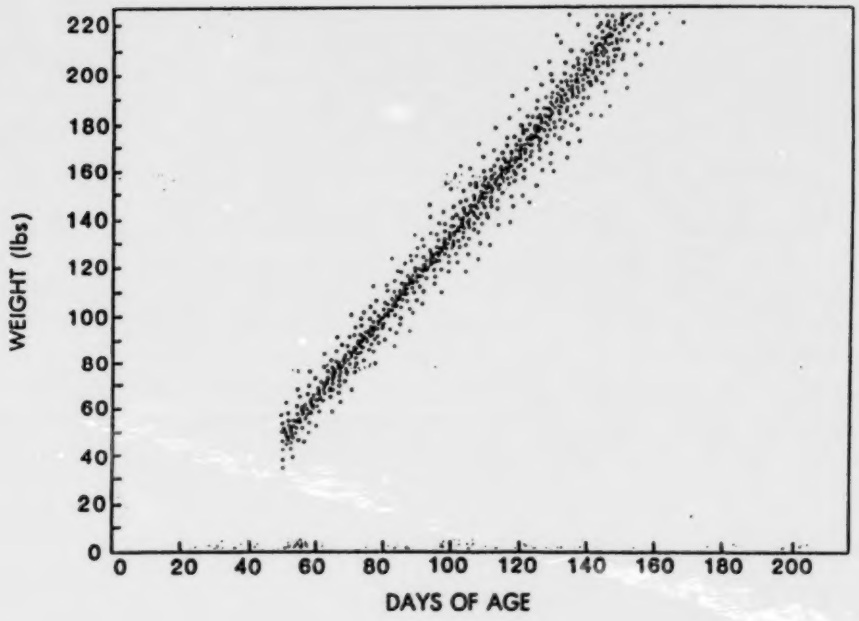
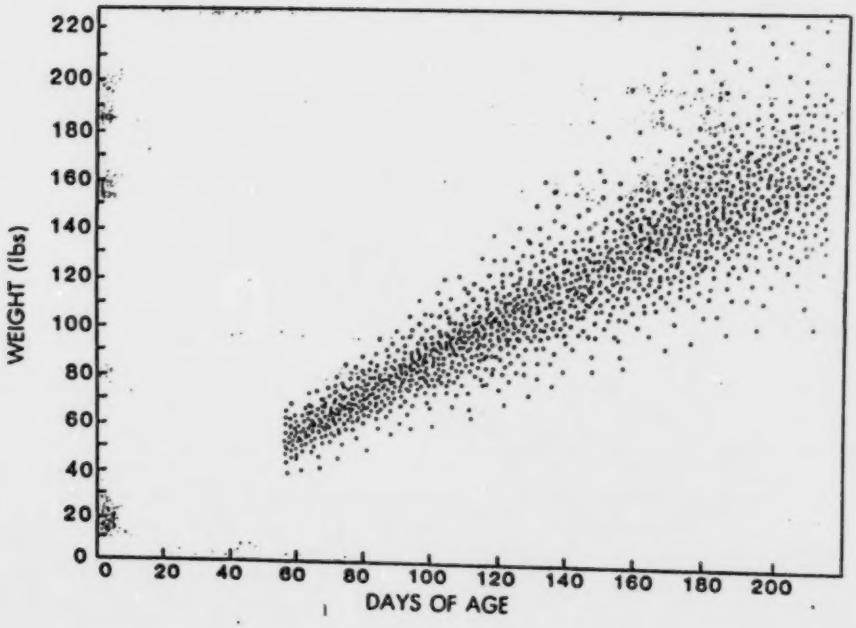


Figure 2



GOOD HUSBANDRY MAKES DOLLARS AND SENSE

Paul Hemsworth

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In modern husbandry of pigs, there is considerable opportunity for periods of intense interaction between people and pigs and thus strong and complex social relationships are formed between people and pigs. Dr. John Barnett and I have shown that in commercial piggeries there is a substantial range in the quality of this human-animal relationship and, at the lower end of this range (i.e. where the pigs are highly fearful of humans), the productivity and probably the welfare of the pigs are at risk.

It appears that the manner in which the stockperson handles his/her pigs can have marked effects on their level of fear of humans. It is my objective in this paper to demonstrate the importance of the behaviour of humans on this human-animal relationship and thus on the productivity of pigs. Our knowledge of ways of reducing level of fear of humans by pigs is in its infancy, nevertheless we believe that we can provide some useful advice and this will also be presented in the paper.

HOW DO WE MEASURE LEVEL OF FEAR OF HUMANS?

Before considering the consequences of a high level of fear of humans by pigs, it is useful to briefly describe how level of fear of humans is measured. A standard 3-minute test is imposed on the pig and we equate the amount of approach to an experimenter by the pig with the level of fear of humans by the pig.

Basically this test involves individually introducing pigs to a 3 x 3 m arena for a 2-minute familiarization period. The objective of this brief period is to allow each pig to become reasonably familiar with the arena to the extent where the novelty of the arena does not interfere with the behavioural response of the pig to the experimenter. After this familiarization period, the experiment enters the arena and remains stationary, and during the next 3 minutes the approach behaviour of the pig is recorded. We propose that pigs that are highly fearful of humans will show little approach to the experimenter.

THE CONSEQUENCES OF A POOR HUMAN-ANIMAL RELATIONSHIP

Over the last 6 years we have conducted a number of experiments to examine the consequences on the pig of high levels of fear of humans. This research was initiated following the finding in a study of 12 very similar one-man farms that the level of fear of humans by sows was negatively correlated with the reproductive performance of the farm (Hemsworth *et al*. 1981a): At farms where sows were highly

fearful of humans, reproductive performance was lower than at farms where sows were less fearful of humans. We proposed that the behaviour of the stockperson was the most likely factor responsible for the differences between farms in level of fear of humans and productivity.

In these subsequent experiments (Hemsworth et al. 1981b, 1986, 1987; Gonyou et al. 1986), a number of handling treatments were imposed which resulted in a substantial range in the level of fear of humans by pigs (see data on the average time to first interaction with experimenter in Table 1). These handling treatments varied from treatments which discouraged approach to humans, by using aversive (negative nature) handling whenever the pig approached, to treatments which encouraged approach to humans, by using apparently pleasant handling whenever the pig approached the experimenter. The former treatments involved either slapping or briefly shocking the pig with a battery-operated prodder while the latter involved either patting or stroking the pig. The handling treatments were briefly conducted either three or five times per week, but an important feature of the methods was that the treatments were only imposed whenever the pig approached or remained close to the experimenter. As shown in Table 1, the aversive handling treatments increased the level of fear of humans, depressed growth rate in young pigs and depressed reproductive performance in adult pigs.

TABLE 1 THE EFFECTS OF HANDLING TREATMENTS ON THE LEVEL OF FEAR OF HUMANS AND PERFORMANCE OF PIGS IN FOUR EXPERIMENTS

Experiment and Parameters	Mean for Handling Treatment Pleasant	Minimal*	Aversive
1. Hemsworth et al. (1981b)			
Time to interact with experimenter (sec)+	119	-	157
Growth rate from 11-22 weeks (g/day)	709	-	669
Free corticosteroid concentrations (ng/ml)#	2.1	-	3.1
2. Gonyou et al. (1986)			
Time to interact with experimenter (sec)+	73	81	147
Growth rate from 8-18 weeks (g/day)	897	888	837
3. Hemsworth et al. (1987)			
Time to interact with experimenter (sec)+	10	92	147
Growth rate from 7-13 weeks (g/day)	455	458	404
Free corticosteroid concentrations (ng/ml)#	1.6	1.7	2.5
4. Hemsworth et al. (1986)			
Time to interact with experimenter (sec)+	48	96	120
Pregnancy rate of gilts (%)	88	57	33
Age of a fully co-ordinated mating response by boars (days)	161	176	193
Free corticosteroid concentrations (ng/ml)#	1.7	1.8	2.4

* A treatment involving minimal human contact.
\+ Standard test to assess level of fear of humans by pigs.
\# Blood samples remotely collected at hourly intervals from 0800 to 1700h.

A finding that is important for the interpretation of these results is that in three of these experiments, the pigs in the aversive handling treatments experienced a chronic physiological stress response. In the absence of humans, the free corticosteroid concentrations of these pigs were higher than those of the pigs in the other treatments. (In the other experiment by Gonyou et al. 1986, corticosteroids were not studied). Corticosteroids are the so-called "stress hormones" and are released from the adrenal glands in response to a stressor. Therefore it appears that the depressions in growth and reproduction of pigs that are highly fearful of humans may be due to a chronic stress response.

It is in situations where the animal is in close contact with humans and is handled individually, such as in the breeding herd rather than the grower herd, that these results have most implication. We propose that the reproductive performance of breeding pigs that are highly fearful of humans is at risk due to either a chronic stress response or a series of acute stress responses interfering with reproduction. The magnitude of these responses would also suggest that the welfare of these animals is at risk.

FACTORS AFFECTING LEVEL OF FEAR OF HUMANS

Our understanding of these factors is limited. However, there are two determinants of the level of fear of humans by pigs. Recent research (Hemsworth et al., unpublished data) has indicated that the parameter, the time to physically interact with the experimenter in the

standard test, is of moderate heritability. It is likely that selection for this parameter would result in a reasonable level of response. However, a factor that is likely to be more important than the genetic factor is the behaviour of the stockperson. There is a considerable change in the level of fear of humans by gilts from the time of selection (to the breeding herd) to entry to the pregnancy accommodation, suggesting that the behaviour of the stockperson around the time of mating may be very important.

In a recent study of 19 commercial farms in Victoria (Hemsworth et al., unpublished data) we examined the relationships between the behaviour of the stockperson around the time of mating and the level of fear of humans and productivity of pigs. There were several important findings in this study. Firstly, we found that there was a substantial variation between farms in the level of fear of humans by pigs. For example, the average time taken by sows to physically interact with the experimenter in the standard test varied from 160 seconds at one farm to 80 seconds at another. Secondly, as in a previous study (Hemsworth et al., 1981a), we found highly significant negative correlations between the level of fear of humans by sows and the reproductive performance of the farm: Sows displayed a decreased approach to the experimenter at farms where reproductive performance was low. This finding together with the previous finding that there is a considerable range in the level of fear of humans by pigs in the industry, indicate the potential that exists to improve productivity in the industry by reducing the pig's level of fear of humans.

The other important finding from this on-farm study was that the behaviour of the stockperson was significantly correlated with both the level of fear of humans by sows and the productivity of the farm. A high proportion of physical interactions of a negative or aversive nature by the stockperson was consistently and strongly associated with a high level of fear of humans and a low reproductive performance at the farm. Physical interactions of a negative nature include hitting, slapping or kicking the pig and the intensity of the interactions varied from mainly mild to forceful. These results indicate that the behaviour of the stockperson is a major determinant of the level of fear of humans by pigs, which in turn can affect the productivity of the pigs. Although it has been suggested that stockpersons that display a low proportion of physical interactions of a negative nature are more likely to be technically competent and skillful and that these latter characteristics are responsible for the superior productivity of their pigs, our observations do not support this contention.

The proportion of negative interactions observed during routine mating activities varied from 38% to 100% across the 19 farms, however the time spent in these activities over a 7-week period around mating varied from 8 to only 57 minutes per sow. This together with other findings, indicate that pigs are sensitive to brief and infrequent bouts of aversive handling. Furthermore, handling of a positive nature may not mask or negate the adverse effects of bouts of a negative nature.

It is also of interest that the stockperson's attitude relating to either the characteristics of pigs or his/her behaviour towards pigs was highly correlated with the behaviour of the stockperson, the level of fear of humans by sows and the productivity of the farm. These relationships demonstrate the substantial potential that appears to exist to reduce the level of fear of humans by sows in order to improve reproductive performance, by employing stockpersons that have desirable attitudinal and behavioural profiles. In the future, this may be achieved through the development of programmes to influence the stockperson's behaviour. Alternatively, or in combination with this programme, it may be possible to select stockpersons for employment in the pig industry on the basis of their attitude. These developments appear to offer the pig industry exciting opportunities and our present research is directed along these lines.

At present, our recommendation to stockpersons is that they should attempt to maximize the number of physical interactions of a positive nature (such as pats and strokes) directed towards pigs and minimize the number of physical interactions of a negative nature. At the same time, stockpersons should attempt to regularly monitor the level of fear of humans by observing the withdrawal response of their pigs to their approach : Fearful pigs are likely to withdraw rapidly, while pigs of low levels of fear are likely to remain. In situations where the level of fear is high or where it is increasing, the stockperson should reassess his/her behaviour towards pigs.

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SPACE AND PLACE IN SWINE HOUSING

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INTRODUCTION

The design of livestock buildings in the next decade will be influenced not only by the usual ubiquitous economic factors, but increasingly by considerations of animal welfare, environmental pollution and socio-economic matters. In a **managed biological system**, the study of space, at several different levels, is a basic requirement of the design of housing for farm livestock. In this paper I intend to draw the two themes together - welfare and space, and to look in detail at their combined effects on the future of pig housing designs.

Welfare is not however easily defined. There is some broad agreement in the general use of the term but a universally accepted precise definition is not yet available. Baxter (1983) for example has presented a zoocentric concept of animal welfare. Here, welfare is conceived as the animal's perception of its own welfare and, though difficult, a suggestion is made for its scientific evaluation. On the other hand, the common use of the term 'animal welfare' is anthropocentric. In this sense, animal welfare and animal rights are concepts transferred from humans to animals, and are therefore subject to the vagaries of emotional judgements. This is not a criticism of emotional judgements, for these are an important aspect of human relationships, but if welfare is so defined then it will be difficult to devise a scientific means of validating different systems and of obtaining unanimous agreement. To avoid further controversy at this stage, I will assume that animal welfare is concerned with those issues described in the 'Codes of Welfare' for farm animals in the United Kingdom. (MAFF 1971, 1983). First however, a brief reminder of the relationship between cost and building space.

The Cost of Space

In the U.K., Wight & Clark (1984) have estimated that a typical part-slatted feeding piggery housing approx. 192 pigs at 90 kg l.w. in 16 pens on an ad libitum feeding system will cost about £143.56 m^2.* The space allowances in their example are 0.56 m^2/pig lying area, 0.21 m^2/pig dunging area and 0.25 m/pig of trough space. Peet (1984) found, in a comparison of the costs of five different fully slatted houses that costs per m^2 of floor space could vary by as much as 60% i.e. from £140.50 m^2 to £225.51 m^2 (see TABLE 1). Space allowances varied from 0.38 m^2/85 kg pig to 0.60 m^2/85 kg pig. How does a producer decide on the best value for money when choosing a new building?

* £185.00 m^2 at Dec. 1987

TABLE 1 Comparison of fully slatted housing features and costs (Peet 1984)

Criteria	MODEL				
	A	B	C	D	E
Number of rooms	8*	9	8	6*	28
Number of pens	64	40	48	90	56
Number of pig places	1200	990	1080	1350	1325
Total lying area excl. hopper space (m^2)**	474.9	340.8	372.0	674	477.1
Number of weeks housed	13	11	12	15	14
Assumed age at 85 kg (wks)	21	19	20	23	22
Assumed average growth rate (kg/day)	0.736	0.870	0.798	0.638	0.684
Space per pig at 85 kg (m^2)	0.45	0.38	0.38	0.60	0.47
Average space per pig housed (m^2)	0.39	0.34	0.34	0.47	0.36
Total cost (£)	107093	67032	79071	94700	86000
Cost per pig place (£)	89.24	67.70	73.21	70.15	64.90
Cost per m^2 floor space (£)	225.51	196.69	212.56	140.50	180.25

* Two separate buildings

** A standard amount of space has been deducted from each pen.

Not only is it clear that there will be some difference in costs depending on the housing system, e.g. part or fully slatted, but in Peet's comparison, the number of rooms or pens and whether they are in one or more buildings, the size and layout of the buildings, the space allowances, and the environmental quality and its relationship to assumed growth rates are all likely to confound the investor. On what evidence have the space allowances been chosen and are they independent of pig performance? (average growth rate). Can we assume that all 5 models can produce the appropriate thermal environment for maximum growth potential or is there an implied relationship between the assumed growth rate shown in TABLE 1 and the environmental quality of the buildings? For example is model B really so environmentally superior to model D that a difference in average growth rate of 0.232 kg/day is possible, and how does it achieve this at a lower investment per pig place? Clearly much depends on the space allowance per pig and the related growth rate, but which set of figures is one to choose? I will return to this question later once we have considered the fundamental requirements for space and the relationship with animal welfare.

Space and Welfare

In the U.K. the relationship of space to welfare has been officially described three times in the last twenty years. The Technical Committee formed to enquire into the welfare of animals kept under intensive livestock husbandry systems gave it's recommendations in 1965 (Brambell 1965). This was followed in 1971 by the first of the Codes of Recommendations for the Welfare of Livestock (MAFF 1971) and then in 1983 by a revised Code of Recommendations (MAFF 1983). Those aspects of these three sets of recommendations concerned with space are summarised in TABLE 2. The recommendations clearly differ, but is there a recognizable trend or any evidence on which to base a comparison in order to explain the differences? Do the housing systems described by Wight & Clark (1984) and Peet (1984) meet these standards? Can the standards be suitably interpreted for both cases?

TABLE 3 compares the space allowances used by Wight and Clark (1984) and Peet (1984) with the three sets of welfare recommendations.

From TABLE 3 it is clear that only the building described by Wight and Clark (1984) would comply with all three sets of recommendations. In the buildings described by Peet (1984), the almost satisfactory compliance with the 1983 Code is only possible if one assumes that in a fully slatted pen the lying area and the dunging area are inclusive (one and the same). The

TABLE 2 TRENDS IN WELFARE RECOMMENDATIONS FOR SPACE ALLOCATION IN SWINE ACCOMMODATION

	RECOMMENDATIONS BY		
SPECIES	Technical Committee on Welfare of Animals in Intensive Livestock Husbandary Systems (Brambell, 1965)	Code No 2 Pigs (MAFF 1971)	The Welfare of Livestock - Pigs (MAFF 1983)
SWINE Fatteners	68 to 96 kg = min 0.75 m^2/animal > 96 kg = min 0.93 m^2/animal	(incl. maiden gilts) Adequate for sleeping & feeding and of such size that soiling of lying area may be avoided. > 57 kg = min 1 m^2 per 122 kg Proportionately more space for smaller pigs especially in straw yards.	Total floor space should be adequate for sleeping, feeding & exercising Sleeping areas must accommodate all pigs lying on their sides. 20 kg = 0.15 m^2 40 kg = 0.25 m^2 60 kg = 0.35 m^2 80 kg = 0.45 m^2 100 kg = 0.50 m^2
Pregnant Sows	Daily exercise; space to turn round; no tethering	Feed and lie down normally.	Stalls and tethers not recommended.
Boars	No recommendation	Individual adult Living space ≮ 7 m^2 Living & service space ≮ 9.3 m^2 Shortest dimension of pen ≮ 2.1 m	Individual adult Living space ≮ 7.5 m^2 Living & service space ≮ 10 m^2 Shortest dimension of pen ≮ 2.5 m

TABLE 3 Comparison of Space Allowances in 6 pig houses with Recommendations from 3 Welfare Standards (Areas expressed as a % of appropriate standard)

Welfare Recommendation	Peet (1984)*					Wight & Clark ** (1984)
	A	B	C	D	E	
Brambell (1965) ($0.75\ m^2$)	60%	50.7%	50.7%	80%	62.7%	102.6%
Code (1971) ($0.70\ m^2$/85 kg)	64.3%	54.3%	54.3%	85.7%	67.1%	
($0.74\ m^2$/90 kg)						104.1%
Code (1983) Lying area only*** ($0.46\ m^2$/85 kg)	97.8%	82.6%	82.6%	130.4%	102.2%	
($0.48\ m^2$/90 kg)						116.7%

* Based on 85 kg pigs ** Based on 90 kg pigs

*** Excluding exercise and dunging area

code however says "Minimum sleeping areas, **excluding exercise and dunging areas**". In this case models A, B and C do not comply, model E is unlikely to comply and model D will only comply if the additional space required for exercise and dunging does not exceed 0.14 m^2/85 kg pig. The Codes provide no guidance on this latter point.

The question then remains - If the dimensioning of space is an important determinant of pig housing design and space allowances are an important requirement for welfare how are the two to be related?

PIGS AND SPACE

It is not unreasonable to expect that the main linear dimensions of pigs should be proportional to $W^{1/3}$ and that surface areas should be proportional to $W^{2/3}$, where W = liveweight (kg). As early as 1879 apparently, Meeh (1879) aimed to predict surface area from body weight using the general formula $As = CW^{2/3}$ where C is a constant of proportionality having a particular value for each species. Brody et al (1982) and then later Deighton (1932) found that the equation $As = 0.097\ W^{0.633}$, where As = surface area (m^2) and W = liveweight (kg) fitted their data best. Kelley et al (1973) then found that the expression $0.0734\ W^{0.656}$ produced a better prediction for modern 'meat type' female swine. Grommers et al (1970) described four different lying postures for pigs and then expressed the floor contact areas as a % of the total surface area calculated from the Brody equation.

The constant of proportionality varied from 0.016 with the pig in the most relaxed recumbent posture to 0.006 when the pig supported itself on all four legs whilst resting. Hsia (?) has also shown that these postures are related to environmental temperature with pigs adopting full recumbency in hot environments and sternal lying in cold environments.

Petherick and Baxter (1981) and Petherick (1982, 1983) confirmed that the principal linear dimensions of pigs may be adequately expressed in the form $L = kW^{1/3}$ and then they predicted that the floor area occupied by an individual pig may be expressed in the form $Af = CW^{2/3}$ where C = 0.019 for sternal recumbency and C = 0.024 for full recumbency. It is to be expected that these values should be greater than the floor contact areas by Grommers et al (1970). For the individual pig, it seems reasonable to assume that the area it occupies when resting will be proportional to $W^{2/3}$, modified by a coefficient indicative of resting posture. For groups of pigs, the occupied space could be estimated from the expression $S = N \leqslant k_i B_i$ where S is the total occupied space, N is the number of pigs in the group, k_i the proportion of pigs performing the i^{th} behaviour at any one time and B_i the static space associated with the i_{th} behaviour. Baxter (1984) has suggested that in a thermally neutral environment groups of pigs will occupy space predicted from the equation $N.0.034\ W^{0.66}$ where N is the number of pigs in the group and W is average liveweight (kg). Later studies by Baxter and Zappavigna (1984) suggests that the minimum resting space can be estimated from the expression $0.027\ W^{0.66}$. Petherick (1982) concluded from her studies that a space allocation calculated from $0.030\ W^{2/3}$ to $0.035\ W^{2/3}$ would be adequate for pigs housed on fully perforated floors. The value of 0.5 m^2/85 kg pig used by Peet (1984) in his cost comparison is equivalent to $0.027\ W^{.66}$ This may be sufficient for a resting group but may not provide enough space for some pigs to drink or excrete whilst the remainder continue to lie undisturbed.

Petherick (1983) reviewed the studies on space allocation and pig performance and concluded that pig performance was only

consistently depressed by space per se below a minimum value, and that effects above this value were more likely to be attributed to inadequacies of place rather than space. There is a strong possibility that this threshold value for space allocation lies between 0.019 $W^{2/3}$ and 0.024 $W^{2/3}$. This would equate with 'packing' density at either sternum or full recumbency. In cool environments, Bruce & Boon (1984) have suggested an alternative hypothesis to explain the reduced areas occupied when pigs huddle together or even lie on top of one another. There suggestion indicates that pigs may reduce there occupied space until a stress of $\simeq 200$ kg/m^2 exists. Table 4 summarises the results of these studies and provides several indicators of space allowances for pigs from 5 to 100 kg lw.

It is of interest now to look again at TABLE 1. The data on liveweight gain suggests that pigs enter the houses at 18 kg lw and leave at 85 kg lw. If we assume that the appropriate stocking density for all weights is best expressed by 0.034 $W^{.67}$ then the maximum theoretical capacities of each model at 18 kg and 85 kg lw are given in TABLE 5.

The cost/pig calculated on the basis of these capacities is also given in TABLE 5. Finally, if we assume that the average growth rate is a measure of the superiority of a model and that this superiority is a linear function of cost, then TABLE 5 gives the adjusted cost to accommodate this feature. When we compare the total cost, cost/pig and adjusted cost/pig it is clear that the rank order of lowest to highest changes, and the difference between highest and lowest is reduced from 60% to about 40%. It is of course possible that the theoretical maximum number of pigs could not be accommodated for lack of feeder space, etc. but this does not reduce the effect of the comparison.

PIGS AND PLACES

When a group of pigs is given an amount of total space greater than some minimum "threshold of productivity", then variation in productivity appears to be related more to the provision of places than of space per se. There are several identifiable places in a pig pen. There is the **feeding place** and **drinking place** usually located where the designer has installed the feeder and waterer. The **resting place** and **excreting place** - sometimes defined by the designers arrangement of slatted floors or separate dunging passages, but sometimes determined by the pig regardless of the designers intentions! Within a general excreting area, pigs may also have individual excreting places (Baxter 1977). There may also be other places chosen by the pigs themselves but not readily identified by designers or stockpersons. For example there may also be a **grooming place**, a **play place**, a **safe place** or even a **fighting place**. There may also be more than one of each of these places. Some places may be mutually exclusive and others, because of the distribution of activities across time may be inclusive. For example, Baxter (1984) has suggested that the difference in space allocation between systems with **restricted feeding** and those with ad libitum

TABLE 4 Space Allowances for Pigs from 5 to 100 kg lw

Liveweight (kg)	Threshold of Productivity m^2/pig (Thermoneutrality) $0.019W^{.67}$	Threshold of Productivity m^2/pig (Thermoneutrality) $0.024W^{.67}$	Threshold of Mech. Stress m^2/pig (Cool environments)	Min. Rest Space m^2/pig (Thermoneutrality) ~~$0.087W^{.67}$~~ $0.027W^{.67}$	Occupied Space m^2/pig (Hot environments) $0.034W^{.67}$	Welfare Codes m^2/pig (Thermoneutrality) 1965	1971	1983*
5	0.06	0.07	0.03	0.08	0.10	-	-	-
10	0.09	0.11	0.05	0.13	0.16	-	-	-
20	0.14	0.18	0.10	0.20	0.25	-	-	0.15
40	0.23	0.28	0.20	0.32	0.40	-	-	0.25
60	0.30	0.37	0.30	0.42	0.53	-	0.49	0.35
80	0.36	0.45	0.40	0.51	0.64	0.75	0.66	0.45
100	0.42	0.53	0.50	0.59	0.74	0.93	0.82	0.50

* Resting Area Only.

TABLE 5 Further Comparison of Slatted Housing Features and Costs (See Table 1)

Criteria	Model				
	A	B	C	D	E
Total lying area excluding hoppers (m^2) (Based on 0.034 $W^{.67}$)	474.9	340.8	372.0	674	477.1
Total pigs at entry 18 kg	2014	1445	1578	2859	2023
and at finish 85 kg	712	511	558	1010	715
Total Cost (£)	107093 **(5)**	67032 **(1)**	79071 **(2)**	94700 **(4)**	86000 **(3)**
Cost/pig at entry 18 kg (£)	53.17	46.39	50.11	33.12	42.51
and at finish 85 kg (£)	150.41 **(5)**	131.18 **(3)**	141.70 **(4)**	93.76 **(1)**	120.28 **(2)**
Period of occupation (wks)	13	11	12	15	14
Adjusted Cost/Pig at entry 18 kg (£)	62.84	46.39	54.67	45.16	54.10
and at finish 85 kg (£)	177.76 **(5)**	131.18 **(2)**	154.58 **(4)**	127.86 **(1)**	153.08 **(3)**

(1) Numbers in parenthesis indicate rank order per row from lowest to highest values.

feeding may be due to the inclusive nature of feeding and resting space in restricted feeding systems and the exclusive nature of a least some space for ad libitum feeding. In the latter some pigs may seek access to the feeder at any time. Most designers try to ensure that the drinking place is included in the excreting area and that both are excluded from the resting area. The exception occurs in pens with fully perforated floors. Even here however, some space should be available around the drinking place which does not intrude on the resting space. Pigs may also continue to differentiate resting and excreting places, even in a fully slatted pen.

Where activities are performed by only some pigs whilst the others perform different activities, the places may again be exclusive. Resting pigs will generally avoid areas of activity such as grooming, excreting, feeding and so on. With respect to safe places, McGlone and Curtis (1981) have shown that the provision of 'hides' can reduce aggression and also reduce the amount of wounding on pigs. A more complete understanding of the space/time patterns of activities of pigs in different environments is required.

Places need to be described by at least 3 criteria.

1. Location - the relationship with other places in a total space pattern.

2. The focal object or artifact around which the activity of place is performed.

3. The space required to perform the activity of place.

Designers will need to make an effort to describe places in these terms and to quantify the estimates of space before they proceed to develop new housing systems. There is no substantial body of data on the design of all places in pig accommodation and only a limited effort has been made to quantify the most obvious of these places.

Feeding place

Baxter (1984) using data produced by Petherick (1982) has tried to demonstrate how two patterns of feeding place - linear and point patterns, can be described in relation to the weight of the pig.

Using the following relationships for LW x L pigs (Petherick & Baxter 1981)

$$\text{Breadth at shoulder} - 60\ W^{.33}$$
$$\text{Length from tail to scapula} - 175W^{.35}$$
$$\text{Length from scapula to snout} - 122W^{.30}$$

he has suggested that the minimum occupied area at a linear feed trough with pigs closely packed is $N.0.019\ W^{.67}$ where N = number

of pigs and W - average liveweight (kg). With loosely packed pigs he suggests the expression $N.0.023W^{.67}$. In both cases, the area is measured over the feed trough to the point reached by the pigs snout. In addition he has suggested that there should be a clear distance behind the pigs of $300W^{.33}$ (mm) or $200W^{.33}$ (mm), with close or loosely packed pigs respectively, to allow animals to move out from the group and change location at the trough (FIG 1). At a point source of feed where pigs encircle the feed source he has suggested that the occupied area will be approximately circular with a radius of about $290W^{.35}$ (mm). Extra space again needs to be provided outside this area to allow pigs to move into and out of the group (FIG 2).

Drinking Place

Using similar data to that applied to the design of feeding places, Baxter (1984) has suggested that at drinkers of the nipple or bowl type mounted on a wall, the area occupied by a drinking pig will also be about $0.019W^{.67}$. However depending on the design and operation of the drinker the pig may be able to take up a position anywhere within a semi-circle having a radius of $300\ W^{.33}$ (mm). The design of the drinker may limit the angle of use as shown in FIG 3.

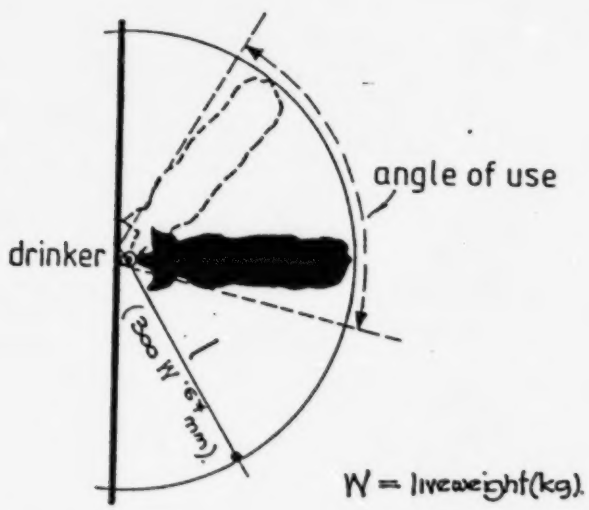
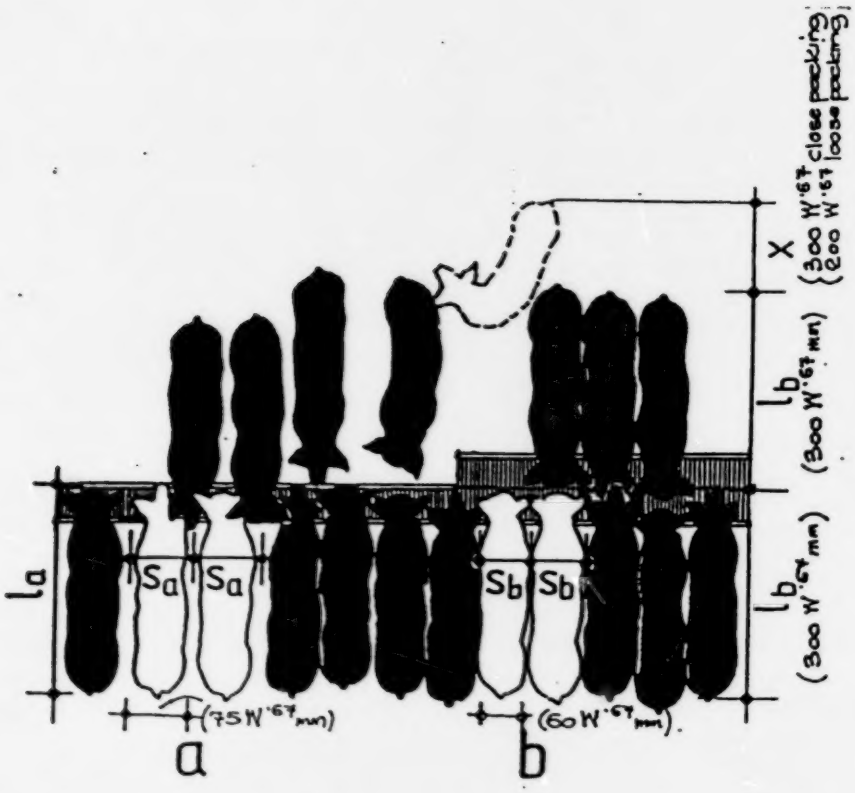


FIG 3 SPACE ALLOCATION AT (WALL MOUNTED) DRINKING PLACE. (After Baxter 1984).

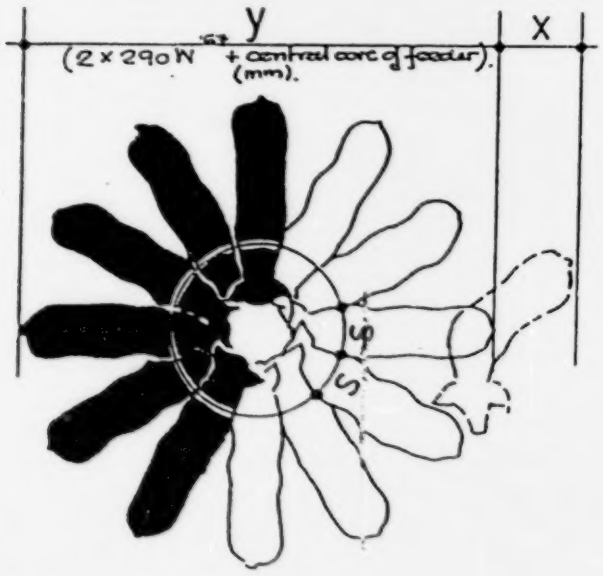
Fighting Place

In an unstable group of pigs attempting to establish a dominance hierarchy fighting will ensue. Using data from Jensen (1982) on the activity of inverse parallel pressing in aggressive encounters, Baxter (1985) has suggested that the space required for this type of behaviour, approximately circular in shape, can



linear feeding W = liveweight (kg).

FIG. 1 SPACE ALLOCATION AT LINEAR FEEDING PLACES. (After Baxter 1984).



point feeding W = liveweight (kg).

FIG 2 SPACE ALLOCATION AT POINT FEEDING PLACES. (After Baxter 1984).

be calculated from the expression $0.11W^{.66}$. Estimating the space required for submissive retreat is however much more difficult. At present there appears to be no information on which to estimate how far an animal must retreat before submission is effective. The 'hides'studied by McGlone and Curtis (1981) may reduce the requirement for 'retreating' space by accommodating an alternative submissive behaviour.

Resting Place

This has already been discussed in an earlier part of the paper. Baxter (1984) has demonstrated how this type of allometric data can be used to calculate the size of 'safe zones' (creep areas) for piglets to rest in farrowing pens. Table 6 is taken from this work. The shape of the collective group of resting pigs will be influenced by the shape of the space available and the thermal conditions provided, either by heat lamps or warmed floors. Conflicting situations can occur when the shape of the space available for the piglets is incompatible with the shape adopted by the resting group when influenced by their thermal conditioning. Thomson (1983) has shown that the average area occupied by a new born piglet in a group under a dull emitter heat lamp was 0.0285 m^2 and under a bright emitter lamp it was 0.0367 m^2. Thermal conditions for at least some of the group under the dull emitter were below thermoneutrality. The bright emitter provided better thermal conditions. These results show remarkable agreement with Table 6. (Column 1)

TABLE 6 Estimated Area and Diameter of Circular Huddled Group of Ten Piglets in Three Temperature Conditions on a Three Different Average Liveweights.

Thermal Conditions	Age & Average Liveweight					
	Birth (1.2 kg)		3 weeks (5 kg)		6 weeks (11 kg)	
	Area (m^2)	Diam (m)	Area (m^2)	Diam (m)	Area (m^2)	Diam (m)
Cool	0.283	0.600	0.735	0.967	1.246	1.259
Thermoneutral	0.384	0.700	1.000	1.128	1.695	1.469
Hot	0.509	0.805	1.320	1.296	2.244	1.690

Excreting Place

Although some useful work has been carried out to try to understand and explain the excretory behaviour of pigs (Baxter 1977) there is, as yet, little data on which to base spatial

calculations. The occupied area of an excreting pig could be estimated from the expression $0.019W^{.67}$ or, in terms of the area commanded, from the area of a circle, the diameter of which is equal to the length of the pig. However the most important data is probably the number of pigs which are likely to excrete at about the same time and the pattern which develops during this vulnerable activity (Baxter 1977).

CONCLUSION

This paper has tried to show that more information is needed on the pig's requirements for space and place. From a typical cost analysis used in pig building comparisons, the paper has demonstrated the ambiguous nature of the data currently used. The relationship between criteria for welfare and space has been listed and discussed in terms of the UK 'Codes of Welfare'.

The welfare space recommendations have been compared with some current applications. An alternative basis for the development of spatial data has been examined which is based on allometric expressions. This has then been used to attempt to define the spatial requirements of places in grouped pigs. Much of the work is speculative and the predictions need to be validated in real situations. However, to be able to design new systems, quantitative data will be needed and it would be preferable if this could be zoocentric rather than anthropocentric. As long ago as 1836, John Claudius Loudon, the Scottish architect and compiler of numerous encyclopaedias of agriculture and architecture wrote "The principles on which the lodging places of all domestic animals are designed must necessarily be drawn from the size of the animal, the temperature of its native climate, its habits of life, and the state of domestication to which it has been brought." (Loudon 1836). We must rethink our approach to the design of pig housing and firmly embrace these principles once again.

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HOUSING PIGS INDIVIDUALLY OR IN GROUPS*

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* This paper comprises two presentations by Seaton Baxter

INTRODUCTION

This paper is in three parts. Parts 2 and 3 will form the basis of two separate presentations. Part 1 is an introduction and common background to Parts 2 and 3.

Part 1 comments on the evolution of swine production systems and the buildings which support them. It suggests that current systems are production oriented and must now face a future in which welfare oriented systems will become more important. The two orientations will need to be successfully combined in new developments. Welfare oriented systems are concerned not only with animal welfare but also human and environmental welfare.

A feature of the welfare oriented components of systems is the high profile of non-monetary values associated with them. The new systems of swine production will require a new form of economic analysis which goes beyond conventional production economics to include welfare and environmental economics.

The designers of buildings to support these new systems will need to evolve techniques of evaluation which include welfare and environmental analyses as well as conventional production functions.

Part 2 of this paper considers the basic arguments for the individual housing of pigs and then, in the light of what has been said in Part 1, examines existing systems of individual housing for boars, sows and growing/finishing pigs.

Part 3 considers two aspects of group housing systems. First it looks at alternatives to some of the individual systems described in Part 2 - mainly those referring to sow housing, and then it raises three fundamental questions, again related to Part 1, but now directed at conventional group housing systems for growing/finishing pigs. The three questions are as follows:-

1. Are there still problems associated with stocking density or space allocation?

2. Are there still problems of dirty pens associated with partially slotted floors?

3. What alternatives are there to fully or partially slotted floors? - this latter point is left for speculation at the seminar.

PART 1
PRODUCERS, PIGS AND THE POPULACE

1.1 Producers and Production

Swine producers spend a great deal of money on buildings and equipment to accommodate swine and then more money to operate and maintain these buildings. At present, in the U.K. it can cost about £200/m^2 ($47/sq ft) to erect new swine buildings.(1) Why do producers invest in buildings? The most important reason is surely that buildings can sustain or enhance the profitability of the swine enterprise. Profitability is measured in financial terms and results from productivity. Buildings must not only contribute to the cost of the enterprise but must also influence, beneficially, the productivity of animals and people. They must be cost effective - their benefits must exceed their costs. Buildings must contribute to either one or both of the following.

- Animal Productivity - By modifying climate, behaviour and resources,(2) and by controlling predators and parasites animals are healthier; they grow faster on less food; morbidity and mortality are lower and reproductive efficiency is higher.
- Human Productivity - By modifying climate, behaviour and resources personnel work more efficiently; they look after more animals in less time; they concentrate on the production aspects of animal husbandry and use machines for routine chores; work routines are undisturbed by inclement weather.

This then is a simplified producer oriented view of buildings and their place in the swine enterprise. The view does not deny that animal welfare and environmental awareness are not part of the system merely that their consideration is subordinate to production.

1.2 Pigs and Welfare

Since the mid-1960's[3] there has been a revival of interest[4] in animal welfare, directed particularly at practices in intensive animal production. The movement is vociferous and articulate; it has a militant wing and political power and in twenty years it has forced changes in the legislation in some countries, united many European countries in intention and forced the publication of national Codes of Recommendations[5]. In addition, and some would argue the ultimate in animal welfare, there has been a regrowth in interest in animal rights and a burgeoning philosophical debate[6]. This paper will not comment on the animal rights issue but will deal with animal welfare in a similar manner to that taken by the Codes of Welfare[5].

There is now no doubt that a concern for animal welfare must be upheld by the designers of swine barns. Sufficient popular and political pressure has been exerted to demonstrate that some existing practices can be banned and new, welfare-oriented systems will be encouraged. There is still much doubt on what is meant by animal welfare and how it is to be measured but here, I take the view that animal welfare is welfare as perceived by the pig. How do we know what the pig thinks about or wants from, its environment? There is, as yet, no well established criteria for answering this question although the application of the performance concept has been suggested as a means of linking biological criteria to design criteria[7]. Performance requirements are intended to describe elements of welfare as the animal itself perceives them and to provide a foundation for animal-centred analysis of building designs. Thirteen performance requirements have been identified for sows as follows[7] -

- o Respiration
- o Thermoregulation
- o Health
- o Sex
- o Neophilia/Recreation
- o Thirst
- o Sociality
- o Hunger
- o Sleep
- o Living Space
- o Maternal Requirements
- o Predictability and Control
- o Skin Comfort

When all of the requirements have been identified, then peformance critera and finally performance specifications will need to be developed. The former are concerned with the physical expressions of the

performance requirement and so describe the dimension or dimensions, on which the welfare-need can be quantified. The performance specification contains the quantitative description of the welfare-need and identifies the boundaries of welfare acceptability. It is from the performance specification that design criteria for acceptable animal environments are derived for application to the creation of new systems or the evaluation of existing facilities. Though much of the detailed information needed to compile such performance specifications is not yet available there is no reason why the framework for animal centred analysis should not be applied qualitatively now, in addition to the conventional measure of productivity.

1.3 Populace and the Environment

In parallel with the growing concern for animal welfare there has been an even greater and popular concern for the quality of our rural environment. This too, has given rise to militancy, political lobbying and foundation legislation and because it embraces the actions of even more of the public than animal welfare it has and will continue to have a significant influence on the development of swine production systems. People now see the countryside, not just as a source of their food, but as the base for leisure, recreation and pleasure. Their enjoyment of the rural environment is also rooted in their belief of what constitutes rurality, and this believe is strong in nostalgia and concepts of the natural world. However mistaken or out-of-date beliefs may be, they form the foundation of the lay-public's attitudes to modern farming. On the factual side however, there is a strong case against many farming practices on the grounds of environmental pollution and the destruction of wild life. The harmful effects of pesticides and insecticides applied to crops, and growth promoters to animals, have been publicly exposed. The contamination of soil and water and the pollution of the air with dust and odours has given rise to many complaints and litigation.

Now a highly mobile, affluent and basically urban populace, expects more from the countryside and from those who work there. Indirectly, this same populace may expect the conditions under which animals are kept to match their growing moral sensitivities as well as their needs for healthy foods and environments. Swine production systems, to be acceptable in future, will need to be evaluated for their effect on the surrounding environment.

So, any system of swine production must now meet and satisfy three measures of evaluation.

- o Production
- o Welfare
- o Environment

and whilst some compromises will be inevitable it will be important to monitor the continuous change in the weighting of these three measures. At present welfare and environmental concerns are growing at the expense of production. The producers problem is not a lack of awareness of these factors but in what priority order are they to be ranked and how does he produce an economic solution from their aggregation.

The remaining parts of this paper should be read against this new background for acceptable swine production systems.

PART 2
INDIVIDUALLY HOUSED SWINE

2.1 Introduction

Why should we want to house any pig by itself? - after all the pig is naturally gregarious. In the wild state, only the mature boar - outside the breeding season, and perhaps the sow about to farrow will, for a brief spell, seek seclusion and solitude.

There are several possible general reasons -
- o the pig kept on its own is more productive.
- o the pig kept on its own makes labour more efficient.
- o the welfare of the pig is better when kept on its own or,
- o the pig wants to be on its own.

These reasons may be amplified by more specific statements as follows.
- o the pig is dangerous to all or some other animals and/or to people and property.
- o the pig is valuable and it might be injured by other animals or damage itself if kept in a group.
- o the pig is ill and needs special treatment or needs to be isolated from other pigs.
- o the pig needs to be protected from the adverse conditions of a competitive social environment.

Where productivity may be measured on a herd basis, animal welfare is measured at the individual level and it is possible that some animals will be better off in individual accommodation for at least some period of time. It is therefore also possible that some forms of acommodation, which are at present criticised, may in fact be supportive of animal welfare. Much depends on how we define 'individual housing.'

What is implied in the criticism of the notion of individual housing? Is it any more or less than that one animal is kept alone in one bounded piece of space? Is there a difference between a boar in a pen and a sow in a stall? Is it the degree of spatial confinement that is of concern in animal welfare rather than the idea of the single animal in a pen or stall? For example, the boar pen is acceptable because it provides the animal with 7.5 m^2 (80 sq ft) of space and the stall is not, because it only provides the sow with 4.3 m^2 (14 sq ft) of space! Is it more than space per se? The sow stall is not acceptable, not just because of its small size, but because it limits the behaviour of the sow!

If so, which behaviours can be limited, if any, and limited in what way and by how much? Housing will always affect behaviour and usually will limit the extent of some behaviours. The sow stall or tether clearly prevents the sow from turning round or walking about. Is the former of higher priority than the latter? Is walking about more important than the reason for doing so? e.g. exploration, for the satisfaction of the desire to explore requires more than just the space in which to walk around. Clearly if spaces are to be designed to accommodate behaviours then they must have 'quality' aspects as well as quantitative dimensions. What part does 'time' play in decisions about the welfare of animals living in the space/time continuum? The Codes of Welfare say little about time and a lot about space. If a pig spends 80% of its time lying resting, is it accceptable to assume that designs need only provide space for activities for about 5 hours per day? If so, which 5 hours? Is it possible to aggregate time for behaviour e.g. 1 days freedom in every week? And so the questions go on with few having any satisfactory answers. Three questions would appear to be paramount when considering individual or for that matter group housing - how much space, to be used for what activities at what times and with how much freedom to choose? Some of these points will be dealt with for specific situations.

2.2 Housing of Boars

Mature boars are large, powerful animals and a potential source of danger to other animals and people. A good breeding boar may also be very valuable and so it would not be unexpected to find these animals housed individually.

In practice, mature working boars are generally housed individually with the oestrous sow or gilt during mating and in individual pens whilst they are resting. These latter pens may or may not always be located within sensory stimulating distance of sows and gilts. It has been shown however that, mature boars housed individually near sexually receptive females, are superior in copulatory performance to boars housed in social or semi-social restriction[8]. The stimuli presented by the proximity of sexually receptive female pigs would appear to be necessary to maintain high levels of sexual behaviour in mature boars. Mature boars that have been socially isolated may require a period of up to 4 weeks in close proximity to sexually receptive females to be restored to full sexual

prowess.[8] It has also been suggested that boars with a previous history of high copulatory performance may require a higher level of sexual stimulation in the long term to maintain their superior performance. So the evidence to date suggests that, whether active or resting, mature boars should continue to be housed in close proximity to sexually receptive females.

Mature boars have however, been housed in small permanent groups. This appears to have had no adverse effect on copulatory performance, social behaviour or physical condition of the boars and serious aggression was not a problem.[8] The improvement in physical condition when compared with individually housed mature boars was however, attributed to the greater availability of space for exercise and the physical interactions within the group. Extra exercise has not, however, been shown by others to have a direct, positive effect on libido or semen characteristics but it is possible that the improved fitness resulting from exercise may lead to a longer productive life.

There is, however, little evidence that space restriction has an effect on sexual behaviour and there is a scarcity of good design data on boar pens. In reported experiments, individually housed boars were provided with an area of 2.5 m^2 to 3.75 m^2 in concrete floored pens and boars in groups of four had an area equivalent to 3.75 m^2 per boar. These pens would appear to provide less space than that recommended for commercial use in the U.K.[5] To accommodate the boar alone, an area of 7.5 m^2 is recommended and, where the pen is also to be used for mating, the area should be increased to 11 m^2. Space per se is probably not the most important attribute of a boar pen. The shape of the pen, and the quality of the environment it contains may play an important role in the provision of a functional and sexually stimulating environment.

The arguments would therefore appear to be adequate, and in some specific cases (danger or value) very strong, for the retention of individual housing for mature working boars, although small group accommodation need not be rejected.

For the immature boar however the situation is different. The early period in a boar's life is important for learning and social development. The social environment which a young boar experiences during development can effect the way he reacts when exposed to oestrus females. Immature boars, allowed physical

contact with other boars or immature females and accommodated within sight, sound and smell of mature oestrus females, may be sexually more aggressive and better breeders than boars reared in social isolation. This work has shown that rearing boars from about 20 days of age under conditions of social isolation, where the animal is denied both visual and tactile stimulation with other pigs, reduces courting activity and copulating performance. Poor copulating performance was attributed to lack of sexual motivation rather than to poor mating dexterity. From a practical point of view there would appear to be sufficient evidence to suggest that immature boars should not be housed individually and in isolation from other pigs.

2.3 Housing of Sows

Breeding sows and gilts have been kept in individual pens during lactation and gestation at least since the time of the Romans.[9] Even such close confinement as that exhibited in stalls and crates is not a modern practice although it has become common place in the last 30 years.

However, the last decade has witnessed an escalation of the public outcry against close confinement of sows in lactation and gestation but particularly the latter. The criticism is not supported, in the main, by some producers because it is not founded on poor productivity - man or animal. Indeed it would be remarkable if such criticism had been founded on poor productivity, for the systems were developed by producers to increase productivity, and their success and rapid adoption is evidence to this effect. However even measured on the basis of productivity, close confinement systems are not ideal, they are only better than the systems (group housing) which they replaced.

The benefits claimed by producers for keeping sows in individual accommodation are as follows.

- o Better control of feed intake.
- o Elimination of fighting between sows.
- o Easier management of the individual sow.
- o Reduction in labour and better working conditions

and additionally, in the case of the lactating sow -

- o Reduction in the crushing of baby pigs.

The disadvantages of the system are

- o Higher capital investment and more sophisticated equipment.

- o Behavioural restrictions on the individual animal
- o Traumatic injury to feet, legs, tail, head, etc. and in the case of the non-pregnant/pregnant sow
- o Difficult detection of oestrus especially in first litter sows.

Confining sows in the smallest space possible e.g. crate or stall, is the expected response to high capital investment whilst at the same time retaining many of the benefits listed above.

The productivity of sows in close confinement is difficult to fault, so the major criticism is based on animal welfare. Present evidence bases this criticism on the sows suffering distress and mental deprivation. The main evidence for distress in closely confined sows is presented as follows.[10]

- o Immediately after tethering, sows make strenuous efforts to escape. The only explanation for this seems to be that restraint is strongly aversive.
- o Elevated cortisol in response to tethering is consistent with behavioural observations and provides physiological evidence of distress.
- o The stereotypes that sows develop following confinement may be adaptations to help cope with stress. Baxter[10] also concludes from analogous situations that sows performing stereotype behaviours are not so much 'coping' as suffering clinical neurosis.

Although the evidence presented refers primarily to pregnant tethered sows, the case against the farrowing crate and sow stall would appear to be equally strong. The farrowing crate however, at least for the first four or five days after farrowing may contribute to the survival and the welfare of the baby pig.

Given the present evidence, it is not difficult to appreciate why producers can claim productivity benefits and welfarists claim animal distress, from the same system. However it now appears that the close confinement of sows must be replaced with appropriate alternatives. Such alternatives are likely to come from the following notions.[11]

- o Sows could be housed individually for only part of the day and released to exercise alone or in association with a small number of other sows. The system could be controlled by management or operated voluntarily by the sow e.g. free access stalls or cubicles.

- Sows could be housed individually (on welfare grounds) for only part of pregnancy (early or late) and thereafter kept in small groups.
- Individual pregnant sows could be housed with less competitive pigs - weaners or growers/finishers. The sows mature weight and status should allow her to take the dominant role and perhaps control any aggression in the group without harm to herself. Sociality would then be accommodated.
- Sows could be housed in groups but fed and watered individually either in feed stalls or electronic sow feeders.
- Sows could be housed in groups in large spaces with well distributed resources for feeding, watering, resting, exercising, playing, etc.
- Where aggressive behaviour is a problem in group housing systems it might be reduced by genetic or pharmacological means.

For the farrowing sow the following ideas might be considered.

- Confine the sow for only a few days after farrowing then release in pen with her litter.
- Confine the sow for only a few days after farrowing then allow her freedom to be with, or away from, her litter and with/without the company of other sows.
- Reduce the length of the lactation period.
- Do not confine the sow but remove the litter except at suckling periods.

2.4 The Housing of Baby Pigs

Newborn baby pigs are highly vulnerable to climatic stress, disease and trauma. Even under relatively good environmental conditions undernourished, though potentially viable pigs, may succumb. Competition from strong litter mates may be the primary cause of undernourishment and later of other forms of deprivation e.g. warmth. The obvious solutions to such a problem is to remove the pig from the competitive environment and to house it individually where it can be adequately attended to. Though such a practice is uncommon, it has been studied and may be economic in large herds with a constant supply of 'underprivileged' pigs. The use of such an 'intensive care unit' is based on welfare as well as productivity grounds. The young pig is only housed individually until it is strong enough to compete successfully with its pen mates.

2.5 The Housing of Finishing Pigs

The practice of fattening pigs in individual stalls has been described as early as 1807[9] and for a short time in the 1970's, it was re-established on a small number of units in the Netherlands and Ireland. Although pigs in individual stalls are reported to grow faster than contemporaries in groups, the high capital investment is hard to recover.

The use of only a small number of individual stalls to house 'slow finishing' pigs, sick pigs or 'nuisances' (tailbiters) has also been practised and evaluated in Scotland.[12] (See Figure 1)

Where the grading system at slaughter is such that there are significant financial advantages for getting all pigs into the correct narrow weight-band, then an investment in stalls for 'slow finishers' may be appropriate. In this system some pigs are only confined for a period of 2 or 3 weeks prior to slaughter. The practice is not common and is unlikely to be so under the present concern for animal welfare, although there are currently no specific conditions for its rejection. For the injured pig, the system has some welfare advantages.

PART 3
GROUP HOUSED SWINE

The group housing systems discussed in this part of the paper fall into two categories.

(1) Speculations on the new systems of group housing which have resulted from the criticisms of some of individual housing systems described in PART 2.

(2) Discussion of problems and potential problems of existing group housing systems.

The first category will tend to concentrate on sow housing systems and the latter on housing for grower/finisher pigs.

3.1 Housing Sows in Groups

The housing of gestating sows in groups was the normal system on swine units in the U.K. up to the late 1960's when, for the larger units, it was gradually replaced by individual stalls. The rasons for this change can be found in PART 2 of this paper. However, not all producers adopted the individual stall system and developments in group housing did not altogether cease. Now under a variety of pressures to change, producers are again reconsidering group housing for pregnant sows.

A brief review of previous systems is therefore pertinent for some may be reintroduced. (modified or intact) In areas where the weather is not too severe systems of indoor/outdoor housing have been traditional. Housing consists of a row of low sties or kennels, each designed to accommodate a group of 6 to 10 sows with an unroofed concrete yard on the far side of which is a row of individual feeders appropriate to the number of sows in each pen. In the sty, about 1.00 m^2/sow space (10.8 sq ft) is provided and this, is littered with straw. In the outside yard, about 2.0-2.5 m^2/sow (21-27 sq ft) is provided. The kennel is usually only about 1.600 m high and preferably fully insulated. There is usually a 150 mm step at the entrance to the kennel and an additional 75 mm high kerb to retain bedding. The yards are divided by gates which swing to shut the sows into the kennels whilst the yards are cleaned by tractor propelled scraper. It is common practice to include boar pens in the range of sties, not only for convenience in handling the stock but also because the proximity of the boar assists in bringing the sows on heat.

In areas with severe weather, the same system can be totally enclosed within a simple building shell.

A modification of this system devised in the 1970's, is the sow cubicle or free stall (see Figure 2). The sow cubicle is similar in size and construction to the sow stall and it must cater for similar functions like feeding, standing and resting. Acces to the cubicle is however voluntary and each sow in a small group has a cubicle available to itself. Extra space, amounting to about 1.70m^2/sow (18 sq ft) is available for group activities, exercise, drinking and excretion. Because sows are not expected to defecate or urinate in the cubicle, then no provision is made for a perforated floor. The solid floor of the cubicle should be insulated or continuously covered with dry straw bedding. Cubicles are generally enclosed to form well insulated kennels which are warmer in winter than the more open exposed exercise area. It has been observed that, in very cold conditions, sows may try to huddle on top of each other in the cubicles, often causing severe injury and predisposing to abortions. It is possible for the free stall or cubicle to be provided with a rear gate and to be used for partial confinement. Sows may be retained in the stall for a period to rest and feed, then released into the exercise areas for exploratory and other social activities.

One further system is worth describing, as it would appear to be the forerunner of the modern group housed electronic feeder systems. Until the 1970's, the fully enclosed, deep straw bedded system was considered ideal for sow housing. A space allowance of about 3.7 to 4.0 m^2/sow (40 to 43 sq ft) is required and the sows are fed in individual feeders, either in batches or altogether. The feeders are usually raised, 750 mm to 900 mm above the floor of the bedded yard to allow for the accumulation of dung and bedding. The straw required for bedding may be supplied in big bales for distribution by the sows themselves. In order to reduce straw consumption, the system has been modified to provide a raised slotted alley next to the feeders. About 50 to 60% of sows appeared to use this alley for excreting, so reducing the contamination of straw in the resting area. However, even when given a bedded area of about 8.0 m^2/sow (85 sq ft) practical experience showed that some bullying and fighting still occurred especially when a new animal was introduced to a well established group. Group size in this system could be as high as 40 sows whereas the cubicle system operates with groups of 4 or 5 sows.

The latest group housing systems using electronic feed stations are the modern successor to this old system and will be discussed elsewhere at the seminar. In any comparison of the old and new systems, the following points should be noted.

- o Though both systems practice individual feeding, the systems are different and could have a significant influence on sow behaviour. The individual stall feeder was used once or twice daily, access was controlled but all sows were fed at the same time. The electronic feed station allows sows access at anytime and so sows are not fed at the same time.
- o When left open, feed stalls were used by sows as safe resting places. Some sows may have difficulty finding such places in an open bedded area especially if space allocation is less than about 2.0 m^2/sow (20 sq ft).[13]
- o Modern systems allow for a space allocation of about 1.5 to 2.5 m^2/sow (16 to 27 sq ft). At the lower figure space may be at a premium if 'place' resources are adopted by some sows.

Much effort is now being directed to the search for alternatives to the farrowing crate. Whilst there is a desire to free the sow from close confinement, the problem is then to ensure that the piglets are not tramped-on or crushed. The detail of much of this research effort has already been discussed[2] so this paper will consider two experimental schemes which seek to provide the sow with more freedom and social activity during lactation.

The first, the family pen system has been under study and development since the late 1970's. The original development (see Figure 3) was concerned with more appropriate housing conditions for growing pigs. The feature of the new proposals was the enrichment of the social environment. Thereafter the study led to the housing of whole families and it is this latter aspect which is of interest here. The pig family system was initially based on 4 adult sows kept together in 4 pens freely connected through the excretory area.[14] The sows farrow in the pens and their offspring grow up there. No artificial weaning or mixing is practiced. A familiar boar is introduced to the group for 5 to 6 weeks at about 3 weeks post-partum. The boar mates with the lactating sows and any replacements which have been retained from previous litters. Performance in the family pens has been sufficiently successful to warrant

further development of the idea. When compared to the top third of herds recorded by the Meat and Livestock Commission 1987, the sows in the family pen system produced as many piglets per litter and litters per sow per year. Piglet mortality from birth to weaning, however, was almost two times more than the commercial alternatives in the period Jan/December 1986 (20.8% v 10.2%). Overall mortality from birth the slaughter was also greater. The operation of the unit requires a labour unit of about 30 mins/day for 4 sows and progeny over a 157 day farrowing cycle and together with any common chores would give a man/sow ratio of 1 to 56 breeding sows. The latest developments once again are faced with the difficult problem of piglet mortality which has not been overcome by allowing sows more freedom, social contact and environmental enrichment.

The second development of interest retains much of the present common features of farrowing crates in pens but allows the sow more freedom and choice for a greater part of the lactation period.(15) The sow is confined to the farrowing crate during parturition and the first few days of lactation. Thereafter, she is freed from the crate and when fitted with an 'electronic key' she is also free to leave the farrowing pen. The litter remains in the pen until it is old enough (large enough) to escape and follow the sow. What the sow does when she leaves the farrowing pen is of course dependent on what facilities are available to her. She could move into a larger communal space with other sows and boars or she could simply have extra individual space. Each lactating sow, however, can only return to her own pen.

Clearly the 'electronic key' could be used to open other doors. Sows in late pregnancy could be fitted with keys to escape from group pens and to explore the farrowing environment for a few days before parturition.

This system allows the sow more freedom to respond to her natural tendencies whilst at the same time ensuring that the process is subject to the least interferance by other sows. It is possible, however, that the sow, given the extra freedom, will not act in accordance with managements plans, and may farrow in unusual places(16) or provide inadequate mothering for her litter. The system however does allow management to intervene if necessary.

3.2 Problems in Conventional Group Housing Systems for Growing/Finishing Pigs

Group housing is the conventional means of accommodating pigs between weaning and slaughter. A great deal of experience has been gained by producers and many are satisfied with the systems they now use. Where problems arise they often fall into two categories both highlighted by unsatisfactory behavioural responses from the pigs. These are -

- o problems associated with stocking density; fighting, ear and/or tailbiting, etc.
- o problems of 'dirty pens' resulting from indiscriminate defecatory patterns.

When a producer is considering the design of new swine barn, his solution must include answers to the above problems. Often, part of the solution to the above problem(s) is to use a totally or partially slotted floor. However, from a welfare point of view, the slotted floor is viewed with distaste and the liquid manure systems usually associated with slotted floors are considered by many to constitute an environmental hazard. This should lead to speculation on a third potential problem which however will not be discussed in this paper -

- o what would be the effect of reducing or eliminating the practice of perforated floor and liquid manure systems and what are the alternatives?
  (It is important to remember that it is possible to have a perforated floor without a liquid manure system and a liquid manure system without a perforated floor).

3.2.1 Problems of Stocking Density

There now seems to be fewer problems associated with severe overstocking of pens since producers have become aware of the penalties for doing so e.g. lower productivity through depressed growth rate and abnormal behaviours. It would seem that growth rate and/or feed conversion efficiency are only consistently depressed by space per se below a minimum value (minimum threshold of production)[2] and that any effects above this value are more likely to be attributed to inadequacies of place (resources)[17]. This minimum value for space allocation appears to lie in the region of $0.019\ W^{0.67}$ to $0.024\ W^{0.67}$ where W = lw. of pigs in kg (see Figure 4). The present recommendations in welfare codes[5] for

total space/pig exceed these values and are also shown in Figure 4. There is now little reason to believe that pigs allocated space in accordance with these recommendations will suffer depressed performance through lack of space. Two problems still require vigilance however.

1. If environmental temperature in the swine barn rises towards the pigs upper critical temperature (UCT) then more resting space will be required, the minimum threshold value may rise to $0.03W^{0.67}$ and appetite may be depressed. Pigs may also resort to lying in the wet areas of the pen.

2. Even where total space may be adequate, the articulation of the space and the identification of places may not be compatible with the pigs use of the space.

This latter point may be particularly relevant to the problem of 'dirty pens.'

3.2.2 Problems of Dirty Pens' etc.

The conventional method of designing a pen for a group of pigs is simple. The total area is calculated by multiplying the number of pigs by some space allocation/pig. Where restricted feeding is practiced then the length of feed trough is calculated to give one dimension of the pen, then divided into the area to give the second dimension. With ad libitum feeding, some arbitrary ratio of pen length to width is selected. Where part-slotted floors are incorporated a minimum dimension of 1.200 m is chosen and the slotted area extends the length or width of the pen. The drinker(s) would be located over the slotted floor.

Problems associated with stocking density are usually resolved by reducing the number of pigs in the pen.

This method takes no account of the behaviour of pigs and can therefore hardly be defended in welfare terms. More recently a method of designing pens on the basis of allometry and behaviour has been suggested,[18] yet no practical validation of the method has yet been produced. This is unfortunate for the techniques does allow hypotheses to be set and tested. The method does, however, require the designer to consider the behaviour of the pig and to predict a set of initial conditions. To ensure that the dynamics of pen use are also considered, the designer must also simulate changing

conditions resulting from growth, feeding patterns, management, etc.

The following are the sort of rules a designer needs to establish in order to design a pen from the pig's point of view.

- The pig will choose a dry, warm, draft-free area in which to rest. Groups of resting pigs will occupy a space whose area is best approximated by the expression $0.024W^{0.67}$
- The area occupied by resting pigs will be influenced by the environmental temperature. At temperatures below the LCT occupied space will reduce to $0.019W^{0.67}$ and at temperatures approaching UCT, occupied space may reach $0.03W^{0.67}$
- The pigs will progressively occupy the resting area by first lying against walls and other pigs.
- Pigs will avoid commotion areas around feeders, drinkers, etc. when resting.
- Pigs will rarely excrete in the area that has been chosen for resting.
- Pigs will excrete in any space which is left after the resting area has been established.
- In the excretory space pigs will tend to defecate next to walls or corners where they can adopt a protected posture.
- Subordinate pigs may be displaced from an overcrowded excretory area and may then eliminate anywhere.
- Pigs will choose to lie in wet, excretory areas if environmental temperatures rise to near their UCT.

It is worth noting, that in behavioural terms these rules should be applicable to all pens whether totally or partially slotted, littered or unlittered! Although the fully slotted floor caters for the indiscriminate pig, pigs do not change their behaviour just because the floor has holes in it. The same is true of the fully bedded floor, just because all areas might make comfortable resting spaces does not mean that the pig will stop defecating! The above rules need to be tested in practice and then altered and extended as appropriate.

Notes and References

1. All building costs are taken from the 1988 issue of 'Farm Building Cost Guide' produced by Scottish Farm Buildings Investigation Unit. Where Canadian dollars are indicated this is the direct result of applying the current exchange rate $2.4 = £1.00, to UK costs. It is not an indication of the cost of buildings in Canada.

2. All buildings modify climate, behaviour and resources. See BAXTER, S.H. (1987) The Design of Space in Sow and Weaner Housing Proceedings Alberta Pork Seminar, Jan 1987 ppl-41.

3. The concern for animal welfare in farming practices was first highlighted by Ruth HARRISON (1964) in her book Animal Machines London V. Stuart Ltd. It was followed in 1975 by the now famous 'Brambell Report' A Report of the Technical Committeee to Enquire into the Welfare of Animals kept under Intensive Livestock Husbandry Systems LONDON HMSO

4. For a well documented review of Victorian concerns see TURNER, J. (1980) Reckoning with the Beast LONDON J Hopkins Press Ltd

5. Codes of Recommendations for animal welfare exist in several countries but only two are referred to in this paper. They are: MAFF (1983) Codes of Recommendations for the Welfare of Livestock - Pigs, Leaflet 702 AGRIC. CANADA (1984) Recommended Code of Practice for Care and Handling of Pigs. Publication 1771/E. Reprinted 1986.

6. There is now a large body of literature on the subject of animal rights but three texts are worth reading. The first is by P. SINGER (1976) Animal Liberation LONDON Jonathan Cape. The second, which points the finger directly at livestock production in N. America in particular, is by J MASON & P. SINGER (1980) Animal Factories N.Y. Crown Publs Inc. and the third a detailed philosophical study by REGAN T. (1983) The Case for Animal Rights LONDON Routledge and Kegan Paul Ltd.

7. BAXTER, M.R. & BAXTER, S.H. (1984) How to Delineate the Sow's Welfare Needs Ann. Rech. Vet 15 (2) 281-286 This paper gives three examples of performance specifications for respiration, thermoregulation and living space.

8. Most of the interesting work in this field has come from Paul Hemsworth and his colleagues in Australia. Dr Hemsworth will provide a complete update on his work at this Seminar but the following references, though dated, are pertinent.
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HEMSWORTH, P.H., FINDLAY, J.K. 7 BEILHARZ, R.G. (1978) The Importance of Physical Contact with Other Pigs During Rearing on the Sexual Behaviour of the Male Domestic Pig Anim. Prod. 27 201-207

9. See Chapter 2 in BAXTER, S.H. (1984) Intensive Pig Production - Environmental Management and Design LONDON Granada Technical Books pp13-34

10. A brief review of this evidence is given in BAXTER, M.R. (1987) Close Cofinement and Distress in Pregnant Sows - An Interpretation. Res. & Dev. in Agric. 4 (3).

11. These are an extension of the ideas suggested in Chapter 13 of BAXTER, S.H. (1984) see note 9.

12. ROBERTSON, A.M. & BAXTER, S.H. (1971) Housing Slow Finishing Pigs in Individual Stalls Frm. Bldg. Prog. (24) 29-34

13. The sows' use of feed stalls for other behaviours has been discussed recently with respect to the design of a low cost group housing system for non-lactating sows. See PETHERICK, J.C., BODERO, D.A.V. & BLACKSHAW, J.K. (1987) The Use of Partial Barriers along the Field Trough in a Group Housing System for Non-Lactating Sows Frm. Bldgs. & Engng. 4 (2) 32-36.

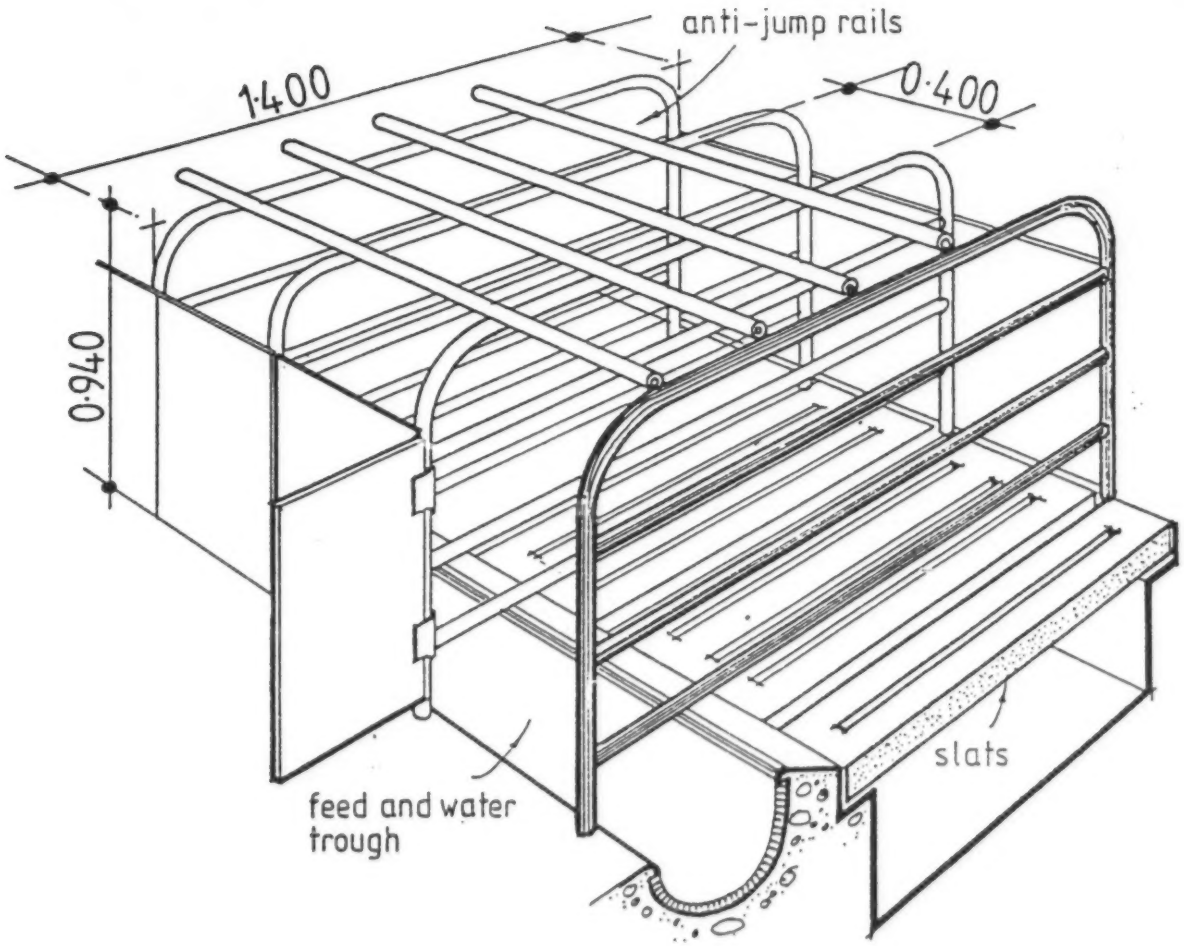
14. STOLBA, A (1981) A Family System in Enriched Pens as a Novel Method of Pig Housing Proc. of Symp. on 'Alternatives to Intensive Husbandry Systems.' Wye, Kent July 1981.

15. The system described here was first seen by me during a study tour in the Netherlands in September 1986. It may also have its counterpart in Sweden.

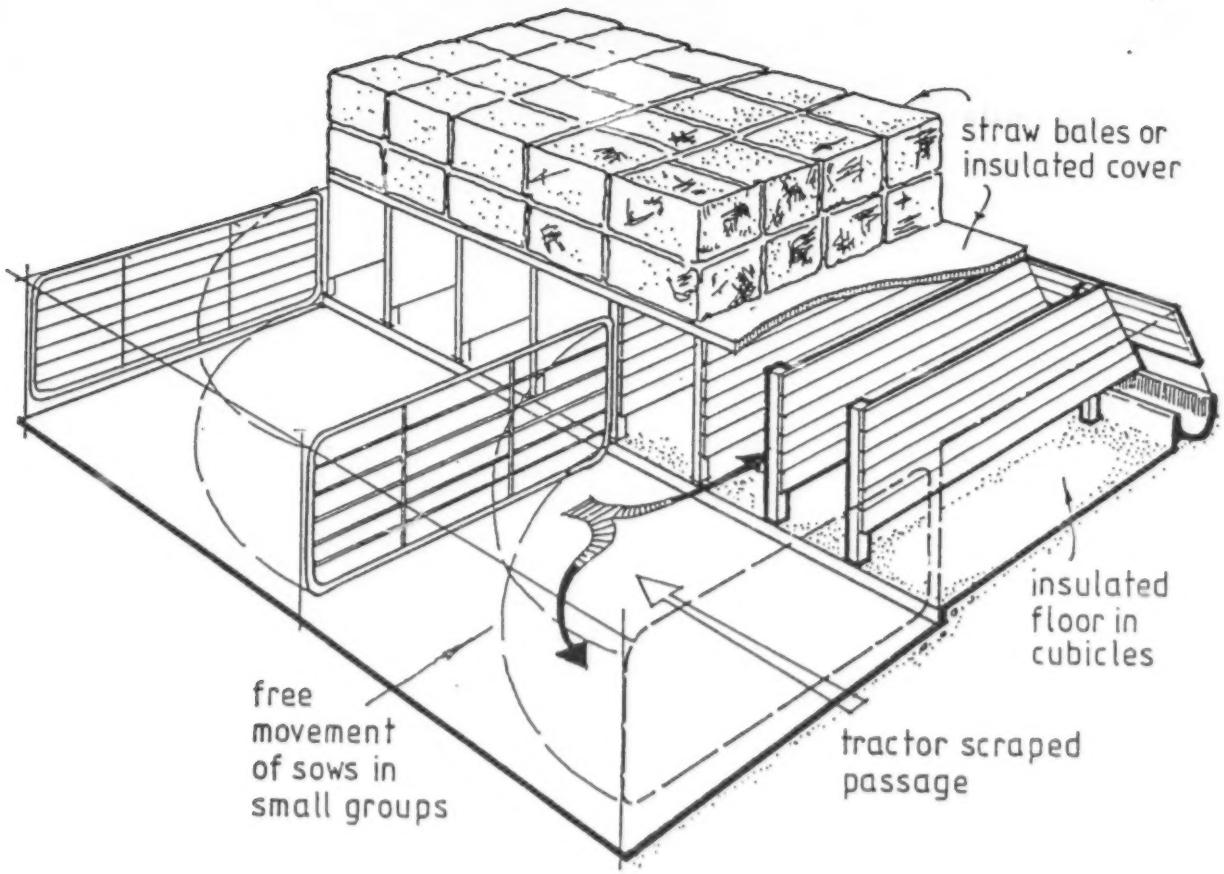
16. See for example a recent study in which sows were given the choice of several farrowing environments. HUNT, K. & PETCHEY, A.M. (1987) A Study of Environmental Preferences of Sows Around Farrowing Frm. Bldg. Prog. (89) July 1987, 11-14.

17. PETHERICK, J.C. (1983) A Biological Basis for the Design of Space in Livestock Housing. In BAXTER, S.H., BAXTER, M.R. & MACCORMACK, J.A.C. (Eds) 'Farm Animal Housing and Welfare' The HAGUE, M. Nijhoff Publs 103-120.

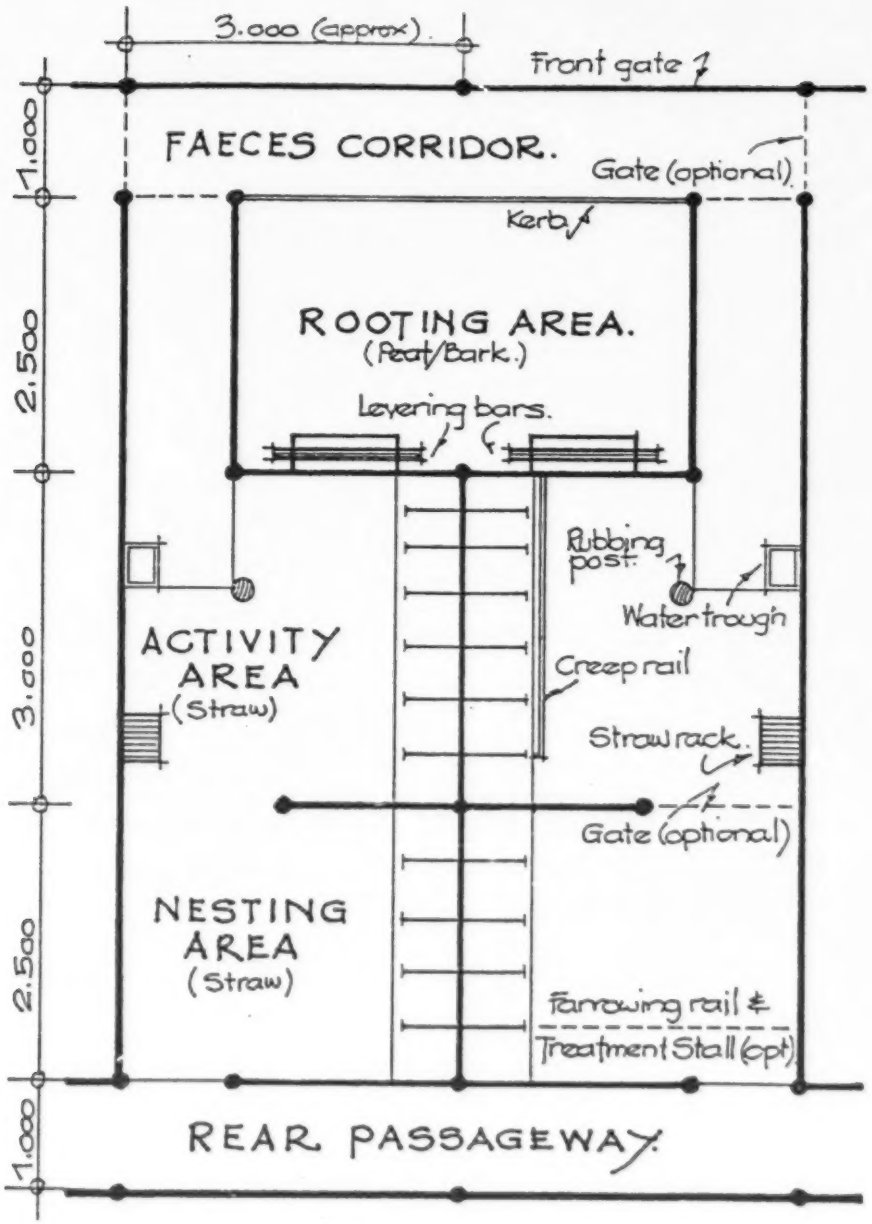
18. See Chapter 8 of BAXTER, S.H. (1984) See Note 9 or for a brief resume see BAXTER, S.H. (1987) Note 2



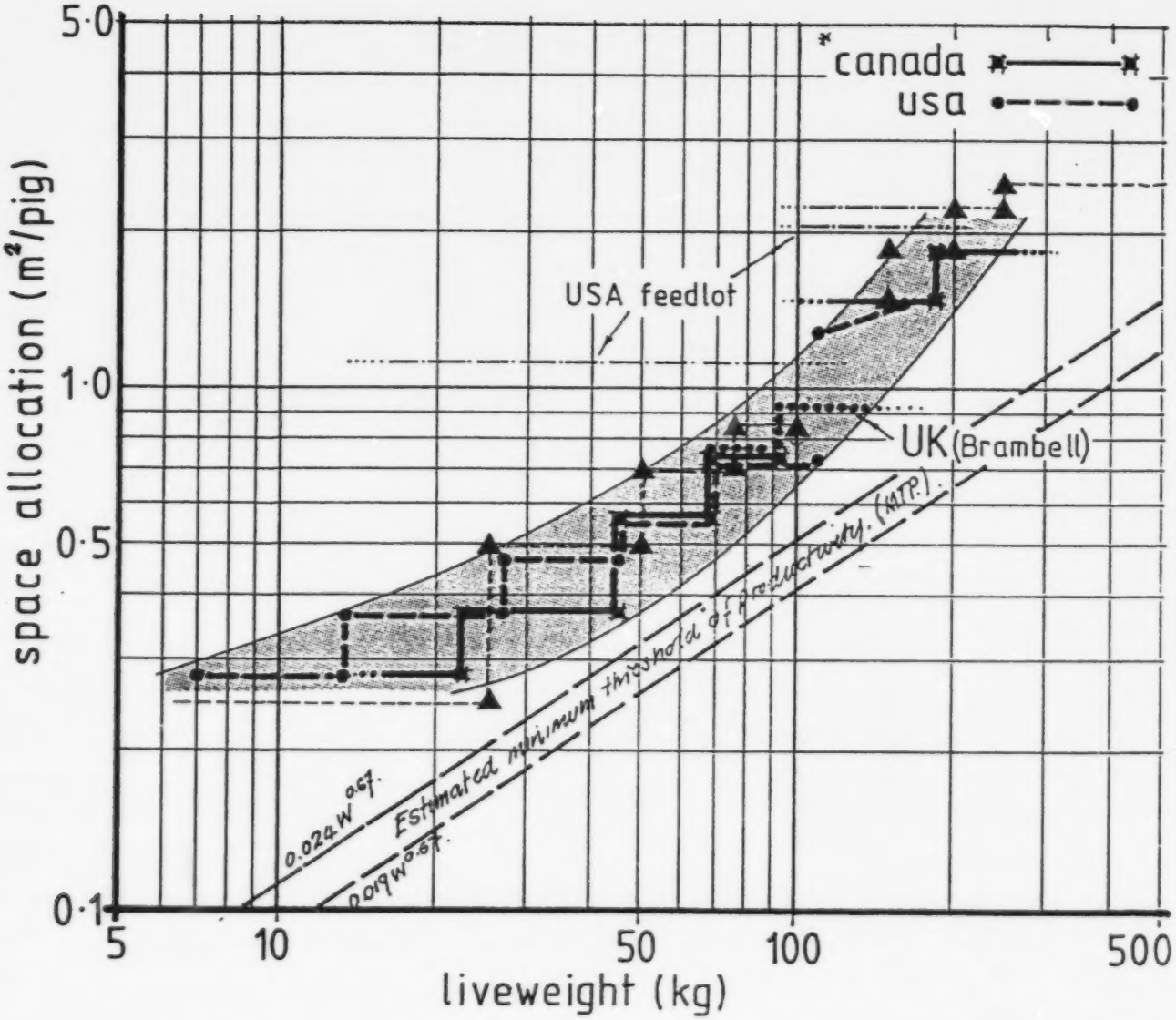
INDIVIDUAL STALLS FOR 'SLOW FINISHERS' INJURED OR NUISANCE PIGS UP TO 90kg. lw.
(From Robertson & Baxter, 1971) Figure 1.



THE SOW CUBICLE OR FREE STALL SYSTEM.
Figure 2.



ENRICHED PEN for PIG FAMILY SYSTEM. (After Stolba 1981).
Figure 3.



CANADA* ~ AHERNE F.X et al. (1974). Swine Production in Alberta Bull. (22) 12th edit.

MTP ~ Average value equates approx. with min. rest area recommended by MAFF (1982).

AGRIC. CANADA. Recommended Code of Practice for Care and Handling of Pigs. 1986 (rep.). Pub. 1771/E.

SPACE ALLOCATION FOR PIGS. Figure 4

Handling and Welfare of the Growing Finishing Pig

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Handling hogs will be easier if you understand their behavior. Good handling practices will improve productivity and meat quality. Stress reduction is important, because handling stress will increase death losses, reduce weight gains[1], lower immune system function[2], and have a bad effect on reproduction[3]. Excitement and rough handling shortly before slaughter will lower meat quality[4,5].

Hog Senses

Wide angle vision enables hogs to see behind themselves without turning their heads. They will balk at harsh contrasts of light and dark in alleys, loading ramps and scales. Hogs raised under artificial lighting often balk and refuse to move towards daylight. Daylight is much brighter than artificial lighting and it blinds the hogs.

Persuading hogs to leave a warm building and move into coldness or daylight will be easier if the hogs are lined up in single file before they go outside. Never place the wall of the building at the junction between the loading chute and the crowd pen. To prevent balking, the loading chute should extend at least two hog lengths inside the building. The other alternative is to enclose the entire loading ramp inside a building.

Confinement hogs will balk if they are forced to look into dazzling sunlight, but they have a strong tendency to move from a darker area to a more brightly illuminated area if the light is not blinding them. A lamp inside a truck will facilitate loading at night. Lamps which illuminate the floor of a chute will attract hogs[6]. The lamps must illuminate the floor and not shine into the eyes of the approaching animals. Hogs exposed to daylight during rearing readily move towards daylight, unless the sun is shining in their eyes.

Flooring Problems

Shadows, puddles and moving objects will cause balking. Hogs will also balk when they encounter unfamiliar flooring, or a floor that wobbles and makes a noise when stepped on. Finishing hogs on expanded metal floors will cause severe handling problems, during marketing. These hogs will be difficult to move on the concrete floors at assembly yards and packing plants. Time is required to enable animals to learn how to walk on an unfamiliar surface. Excessive hoof growth on expanded metal finishing floors also contributes to handling problems.

When pigs are transferred from nursery pens with expanded metal floors to pens with concrete floors, they should be allowed to become accustomed to walking on concrete before driving is attempted. Floors in crowd pens, loading ramps and other areas for hogs are handled should have a rough non-slip surface.

Effect of Genetics

Hog breed affects behavior during handling. Yorkshire hogs required more time to load into a truck than Pietrains or Minnesota No. 1's[7].

Within a breed, different genetic lines will vary in excitability and fearfulness of strange places and people.

Landrace hogs with long ears often balk because they have difficulty seeing. Some genetic lines of Landrace hogs have weak hindquarters and they are more likely to fall down and do the "splits" on slick floors. Observations at packing plants indicated that hogs from particular farms caused handling problems. Animals with weak hindquarters had difficulty walking up ramps. Selecting animals for stronger hindquarters will help remedy this problem.

Solid Fences

Fences should be solid on loading ramps, crowd pens and other hog handling facilities[6]. Solid fences facilitate movement because they prevent the animals from seeing distractions outside the fence with their wide angle vision. The crowd gate in a crowd pen should also be completely solid, otherwise the hogs will attempt to turn back and rejoin herdmates they just left[6]. In assembly yards, packing plants and other places where large numbers of hogs are handled, pen gates along the drive alley should be solid. Solid gates facilitate movement because hogs in the alley will be less likely to stop to investigate hogs in the pens.

Hogs will stop if they are confronted with a solid barrier. This is why a portable panel is efficient for moving hogs. A panel placed in front of a hog will stop it from turning back. A light aluminum panel with a hinge in the middle is efficient for separating hogs in a pen. Pile ups and stress can be avoided by handling hogs in small groups.

A broom can be used to make a hog back up. Sows will readily back out of their crates when tickled on the snout by a broom. The use of electric

prods should be discouraged on hog farms. Repeated prodding increases heartrate to higher and higher levels with each successive prod[8].

Crowd Pen and Chute Design

Hogs have a strong escape response. When two hogs become wedged in a funnel leading to a loading chute, both animals keep pushing forward. One animal will not back up and allow the other hog to pass through. Jamming in a funnel is stressful[8]. Funnel shaped crowd pens used for cattle are not recommended for hogs. A hog crowd pen must have an abrupt entrance to the chute to prevent jamming.

Figure 1 illustrates a hog crowd pen and single file chute with a single offset fence equal to the width of one hog at the chute entrance. The offset step enables one hog to step aside to allow another hog to pass. The crowd pen design also enables the handler to reach both the leader hogs and the hogs in the rear of the group. This prevents pile ups caused by pushing large groups of hogs from the rear.

Twin single file chutes side by side facilitate loading (Figure 2). The two outside fences are solid to prevent the hogs from balking at distractions outside the fence. The divider fence in between the two chutes is "see through" to promote following behavior.

A common mistake is to build chutes too wide. Chutes should be 41 cm to 43 cm (16 to 17 in.) wide. If hogs jam at the entrance, restrict the width of the entrance down to 37 cm to 39 cm (15 to 15 1/2 in.) with a vertical piece of pipe.

Loading Ramps

A hog's heartrate increases as the angle of the ramp increases[8]. The maximum recommended angle for a nonadjustable loading ramp is 20

degrees. If space permits 15 degrees is recommended. On concrete ramps stairsteps with a rough surface are recommended. A 9 cm (3 1/2 in.) rise and a 30 cm (12 in.) tread width are recommended for both hogs and cattle. A 7 cm (2 1/2 in.) rise and a 20 cm (10 in.) tread works well for hogs. On wooden ramps the cleats should have 20 cm (8 in.) of space between them.

Rearing Environment

Rearing environment affects behavior during handling. Hogs raised outdoors with toys to play with and frequent contact with people in their pen were more willing to approach a strange man and walk through a narrow chute, compared to hogs raised in small indoor pens[9]. Hogs raised outside were also easier to load into a trailer than confinement reared hogs[10]. Overcrowding in confinement buildings also increases handling problems.

Animals with previous experiences with gentle handling are going to be calmer and easier to handle in the future. Hogs which have experienced rough handling will remember it and be harder to handle the next time.

Toys

Some confinement reared hogs are highly excitable. This contributes to handling problems and stress. Providing confinement reared hogs with environmental enrichment reduced excitability. Finishing hogs with continuous access to hanging rubber hose toys and weekly contact with a person for five to ten minutes in the finishing pens were less excitable than hogs which received no environmental enrichment[11]. (Table 1). Toys

alone reduce excitability but to a lesser extent than toys plus human contact (Table 1).

Table 1

Excitability Scores for Market Hogs

	Control	Mingle	Drive	Toys	Mingle/ Drive	Drive Toy	Mingle Toy	Mingle Drive Toy
Trial 1	3.25	2.50	2.75	1.75	1.25	1.50	1.75	1.00
Trial 2	2.75	1.00	2.75	2.25	1.25	1.75	2.50	1.50

Experimental treatments were: Control - People never entered the pens and there were no toys. Mingle - Person entered hogs' pen and petted the animals gently for ten minutes each week for the last five weeks of finishing. Five minutes of petting weekly was also effective for reducing excitability in another experiment. Drive - Hogs were driven in aisle five times during finishing. Toys - Hogs had continuous access to rubber hoses suspended from the ceiling. Heavy fiber reinforced hose with an OD of 2.5cm should be used.

Excitability ratings were determined by observers who were blind to experimental treatment. A 1 to 4 scale was used. 1 = calm, approached the observer when the pen was entered; 4 = active avoidance piling up.

These simple procedures can be used on the farm to improve handling, welfare and possibly reduce stress. Confinement reared hogs which had access to toys and small amounts of contact with people in the finishing pens required less force to drive them through a narrow chute[12].

Hanging rubber hoses are superior to chains and bowling balls for hog toys. When a ball becomes covered with manure the hogs tend to stop playing with it. Hogs prefer hanging rubber hoses or cloth strips over chains. They will jerk and shake cloth strips or rubber hoses. This behavior is seldom performed on chains because it hurts their mouths.

Table 2

Toy preference test results

Trial	Toy	Touching frequency	Duration	Biting frequency	Duration
1	Chain	3.6	.07 min.	5.4	0.6 min.
	Cloth	6.6	.15	14.8	2.3
	Hose	4.6	.12	3.0	0.2
2	Chain	5.5	.11	5.8	0.5
	Cloth	8.8	.21	12.6	1.6
	Hose	9.0	.22	9.1	0.7

From: Grandin and Curtis, 1984, University of Illinois
Frequency and duration of touching and biting was tabulated during a 5 minute observation period for each animal for each of ten days. Minutes were recorded in tenths of minutes.

Playing a radio in the barn also helps reduce excitability, because the hogs become accustomed to novel sounds. Choose a station which has both talk shows and a variety of music. Preconditioning hogs to truck sounds should be explored to determine if it would reduce stress.

Optimal Level of Stimulation

Most hogs will probably benefit if they are provided with toys and a radio. There may however, be an optimal level of contact with people which will produce a calm market hog which is easy to drive. If the animals are excitable they will be difficult to handle and may become

agitated and stressed at the packing plant. On the other hand, it is possible to have animals which are so tame that driving is difficult.

Hogs which are excitable and fearful of people may require more contact with people in their pens during finishing than less excitable hogs. The toy and mingling treatments had less effect in trial 2 (Table 2) because the second batch of hogs was less excitable when the experiment started.

The optimal level of contact with people in their pens will vary depending on genetics and previous experiences. Hogs differentiate between people in the alley and people in their pens. To effectively reduce excitability the person must enter the pens.

Breeding animals would probably benefit from greater amounts of positive contact with people than finishing hogs. Young gilts that received gentle petting from handlers had higher pregnancy rates than gilts which received no handling or aversive handling[13].

Piglets raised by calm sows may be less excitable during finishing. On one farm, a dramatic change in piglet and sow behavior was observed with a change in management. The new woman manager calmed down the sows, and the piglets no longer squealed when they were picked up. A piglet's experiences affect its behavior later in life. Piglets that are handled and petted are less fearful of people when they reach market weight[13].

Do Not Intimidate Hogs

If an animal perceives a handling procedure or contact with a person as a threat, stress may increase and productivity may decline. Sows that were fearful, and withdrew from a person's hand, averaged fewer piglets born than sows which readily approached a person's hand[14].

When extra human contact is provided the person must be careful not to intimidate the animals. The person should squat down if the hogs are fearful and move away. He should allow the hogs to approach and never chase fearful animals. In our experiments, weight gains were not affected by petting hogs in the pens or taking them for weekly walks in the alley. Care was taken to avoid frightening or hurting the animals. If the animals feel threatened by a fast moving, looming person weight gains may be lowered[13].

Aversive contact with people in the pens will reduce pregnancy rates[3]. Hogs which were slapped, shocked or snared when they approached a person had reduced weight gains[1]. The animals soon learned to move away from the person to avoid aversive treatment. Even though the hogs learned they could avoid aversive treatment, the person was perceived as a threat when he entered their pens several times a week. Weight gains declined and the animals were in a chronic stress state.

Hogs have long memories. If a boar is beaten it will take a long time for him to learn to trust the handler. When new breeding stock arrives, their initial experiences should be made as pleasant as possible. If they are immediately subjected to painful procedures such as detusking they will associate the people on the new farm with pain.

Dominance

Handlers can increase their control of animals by exerting dominance. The handler exerts dominance in the same manner that another animal would do it. Exerting dominance is NOT beating an animal into submission. Pigs exert dominance by biting and pushing against the neck of another pig. In

a pen of twelve 23 kg (50 lb.) pigs the "Boss" pig repeatedly bit me. Slapping or yelling did not stop her biting. Biting immediately stopped when I exerted dominance by shoving a board against her neck and holding her against the fence[9]. The board simulated the mouth of another pig. I became the "Boss Hog" and the pig now allowed me to pet her. This method should be explored for controlling boar attacks. Possibly, exerting dominance at a young age would help stop future attacks.

Restraint

There is a great need for better restraining devices for hogs. Observations at packing plants revealed that hogs seldom squeal while held in the V conveyor restrainer. Animals in the leadup chute usually stop squealing when they feel the V conveyor restrainer against their sides. The V restrainer consists of two obliquely angled conveyors that form a V. The hog's feet protrude through a space at the bottom.

When a pig is placed in a V shaped padded squeeze chute it will relax. Tucking the rear legs up to lift the feet off the floor will cause immediate relaxation. Possibly, pressure along the sides and the belly triggers the same response that induces hogs to lie against each other. One pig repeatedly ran back into the squeeze chute and pressed herself down against padding when the handler was trying to catch her.

Restraining devices which support a hog along the sides of its body or under its belly could be easily developed. When the hog enters the device it would lift it off its feet. Better hog restraining equipment would reduce stress on both the animals and the handlers.

Meat Quality

Months are spent raising a hog and then it is often abused and roughly handled on its way to market. Death losses and bruises will be reduced and meat quality improved if hogs are handled properly during transport and prior to slaughter. A hot, excited hog is more likely to die or have poor meat quality. Overheated hogs are likely to have either PSE (Pale Soft Exudative) or DFD (Dark, Firm and Dry) pork.

Hogs will travel better and meat quality will be improved if they are fasted eight to twelve hours prior to stunning. Longer fasts are likely to cause carcass shrink and water should be provided at all times. During the summer, keep hogs cool, and transport them at night or in the early morning. On hot days, wet hogs prior to loading, but never spray water on an overheated, stressed hog. If the temperature is over 60 degrees, bed trucks with wet sand or wet shavings. Use straw during cold weather. Avoid the use of electric prods, use panels to move hogs.

During hot weather, trucks must be kept moving to prevent heat build up. High temperatures in a parked truck will increase death losses. Unload hogs promptly at the packing plant. Progressive packers rest hogs one to four hours to reduce PSE and hemorrhages in the meat. A short rest allows the animals to settle down and cool off. Showering during hot weather is also highly recommended. Gentle handling in the stunning chute and a reduction of excitement will reduce PSE[4,5]. Well designed chutes are essential to minimize excitement.

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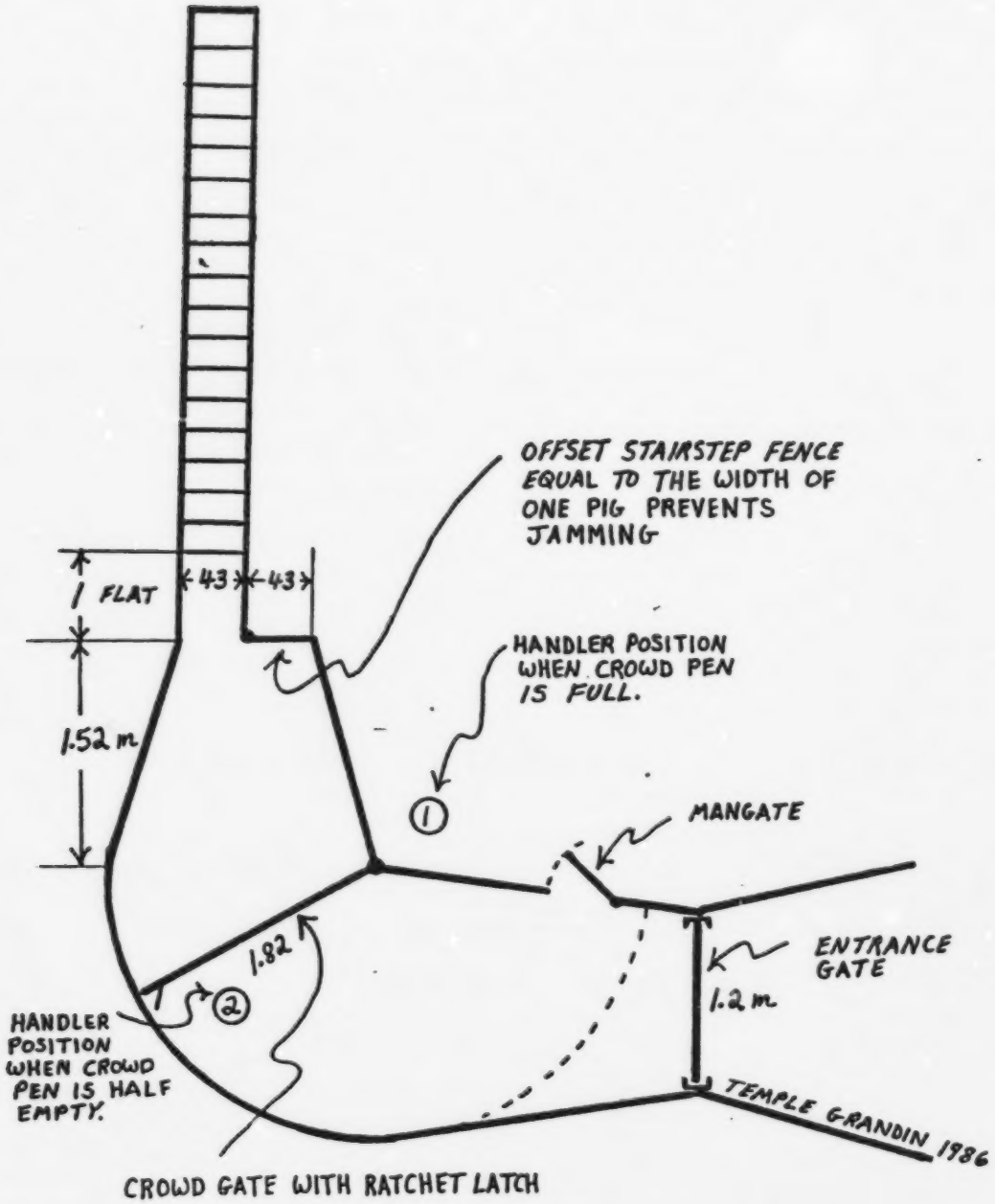


Figure 1. Crowd pen and chute system for handling or loading hogs. The angle at the crowd gate radius point may be varied from 90 to 140 degrees. The handler stands in position 1 when the pen is full. From this position he can reach both leader hogs and hogs in the rear of the group. As the pen empties he pushes the crowd gate and moves into position 2.

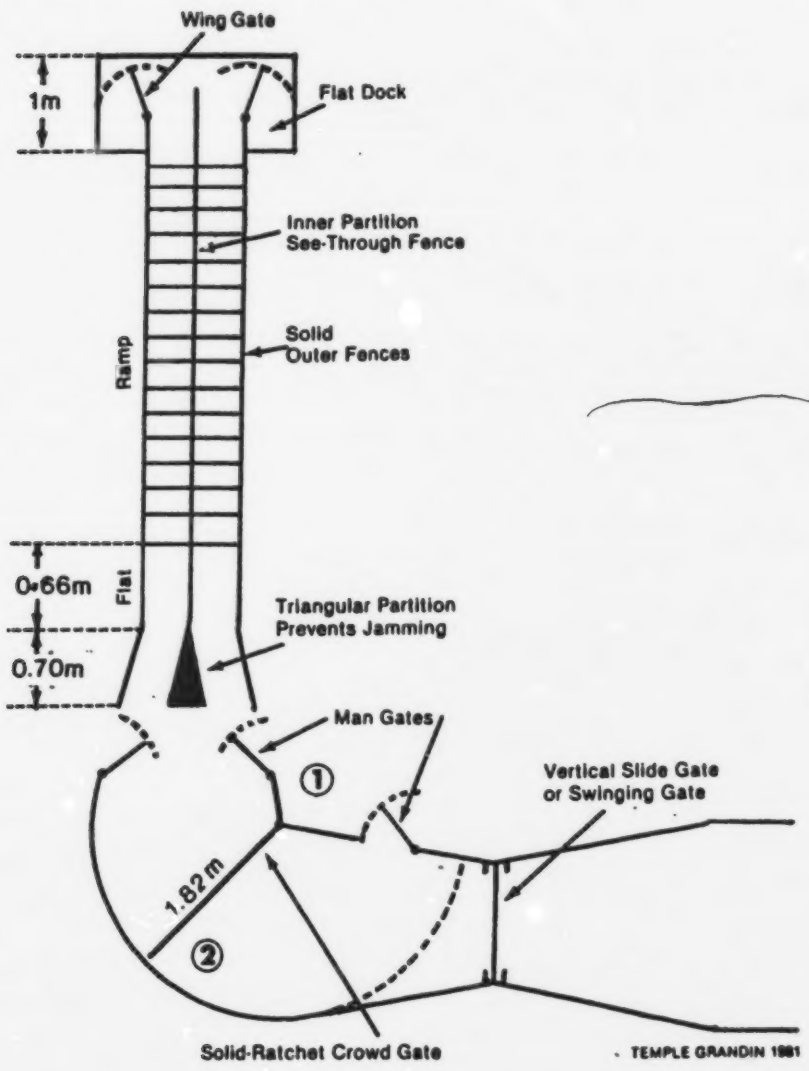


Figure 2. A chute with two lanes is efficient for loading hogs,. The outer fences must be solid, and the inner fence is "see through" to promote following. The triangular partition prevents hogs from jamming at the two chute entrance.

FEEDER BARN VENTILATION - WHAT DO WE KNOW?

The material covered in Dr. Barber's presentation can be found in Section 2 of the booklet "Feeder Barn Design and Management" published by the Veterinary Infectious Disease Organization (VIDO). A copy of this section follows.

SECTION

Ventilating the Feeder Barn

Ventilation is required in any building housing pigs. How well a barn is ventilated will have a large influence on the health and productivity of the pigs. It will also affect the health and well being of the barn operator. Despite the importance of ventilation, the design of a ventilation system and selection of ventilation equipment are often given the lowest priority when planning or renovating a hog barn.

This section outlines the hows and whys of ventilation. It also explores the inter-relationship between ventilation, animal health and productivity. Though several guidelines are offered and one example system is discussed in detail, this is not a comprehensive ventilation guide. Contact an agricultural engineer to properly plan or renovate a ventilation system.

Why You Need to Ventilate

Every pig continuously gives off heat, moisture and carbon dioxide. In addition, pigs shed microorganisms and minute skin particles. When a pig is kept outdoors these contaminants are quickly diluted into the atmosphere. In a barn, however, the contaminants will continuously accumulate unless they are removed. The problem is aggravated by feed dust and manure gases in the barn.

Ventilation is the process which moves clean air through the barn airspace to dilute and remove the contaminants and replenish oxygen levels. There are two basic types of ventilation, natural and mechanical. In natural ventilation systems, air is forced through the building by wind and temperature gradients. In mechanical systems, fans move the air.

There are two types of mechanical systems, one based on positive and the other on negative pressure. In positive pressure systems, fans blow fresh air into the barn to create a positive internal pressure that forces an equivalant amount of air out of the building. In negative pressure systems, fans blow air out of the barn creating a negative internal pressure and causing an equivalent amount of fresh air to flow into the barn.

In all three cases, the net effect is the same—clean air passes through the airspace diluting and removing stale air and contaminants.

Regardless of the system or equipment used, ventilation removes contaminants primarily by mixing and dilution, not by displacement. The following analogy may be helpful. Water moves through a hose in a plug, not mixing with the water ahead or behind. However, this is not the way air moves through a barn. Fresh air particles in an incoming airstream separate out and mix with stale room air. Air leaving the ventilated space is a mixture of air that has been in the barn from a few seconds to several hours (Figure 11).

Just as fresh air is mixed and diluted throughout the airspace, so too are contaminants including disease causing bacteria and viruses (pathogens) shed by sick animals. Since contaminants are not removed without first being mixed in the airspace, they must be continuously diluted to safe, low levels to prevent health problems. For this reason, measures which reduce or eliminate sources of contamination are more effective than ventilation. Remove sick animals to reduce spread of disease producing organisms. Minimize in-barn manure storage and keep pigs and floors dry to reduce other air contaminants.

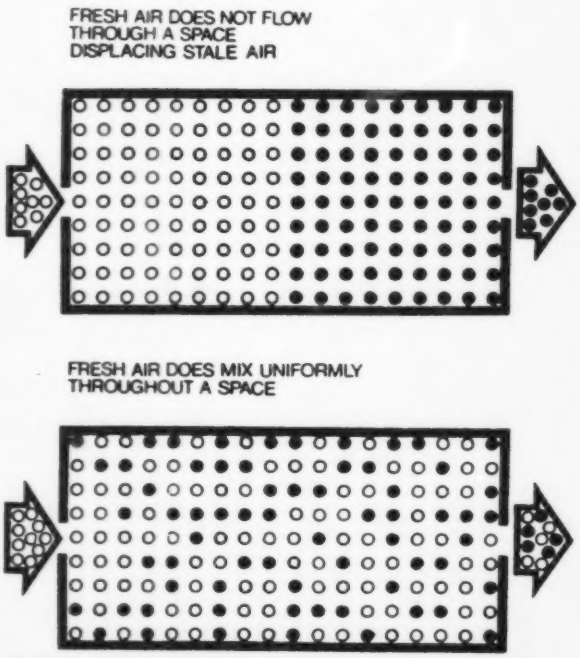


FIGURE 11: *Ventilation occurs by mixing and dilution.*

Ventilation and Keeping Pigs Clean

Ventilation influences animal dunging habits. In pens with a partially slotted floor, the objective is to have pigs dung on the slats and rest on the solid floor area. During winter, cold incoming air that drops into the intended resting area will probably cause pigs to sleep on the slats and dung on the solid floor. In summer, pigs may avoid the intended resting area because it is too warm due to the absence of fresh, cool air.

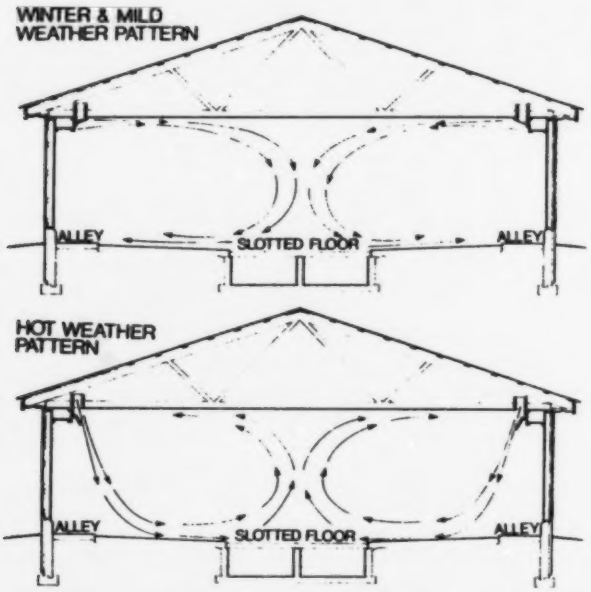


FIGURE 12: *Provide the correct air circulation patterns for barns with a central dunging area.*

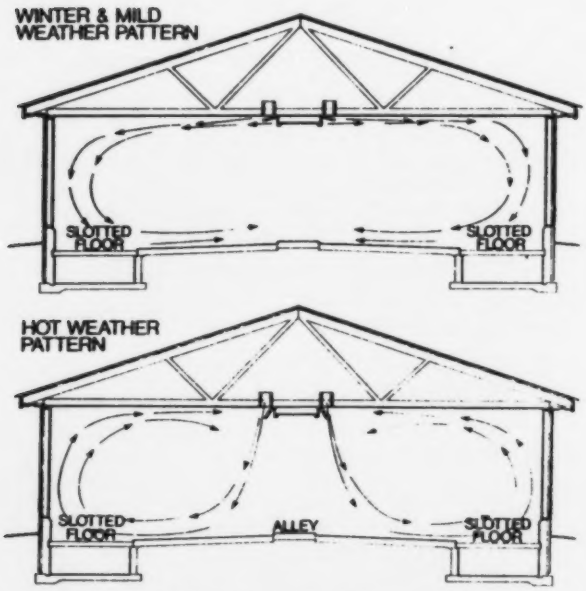


FIGURE 13: *A different air circulation pattern is needed with dunging areas along the outside walls.*

If pigs are not keeping the resting area clean in winter, adjust air inlets to create cooler conditions in the dunging area. In hot weather, deliberately direct fresh air into the resting area.

A Word About Temperature

For all classes of pigs there is a range of air temperatures within which productivity is unaffected. This range, called the thermo-neutral zone, is very small for young piglets and quite large for feeder pigs. The upper and lower limits of their thermo-neutral zones are called the upper and lower critical temperatures.

As the pig digests food, heat is released. In addition, all physical activity produces and releases heat. Within its thermo-neutral zone, the pig can manage this heat to keep body temperature constant.

At the lower (cool) end of its thermo-neutral zone, the pig is able to regulate body temperature by various means including:

(1) constricting blood vessels in or near the body surface to minimize heat loss,

(2) erecting the hair coat,

(3) lying with minimum skin surface exposed to cool floors, and

(4) huddling together with pen mates.

When these mechanisms are insufficient to maintain body temperature, more food energy must be diverted to produce heat instead of growth. The point at which extra food energy begins to be diverted to keep the animal warm is called the lower critical temperature. Obviously, whenever air temperature is below the pig's lower critical temperature, the efficiency of converting food to weight gain is reduced.

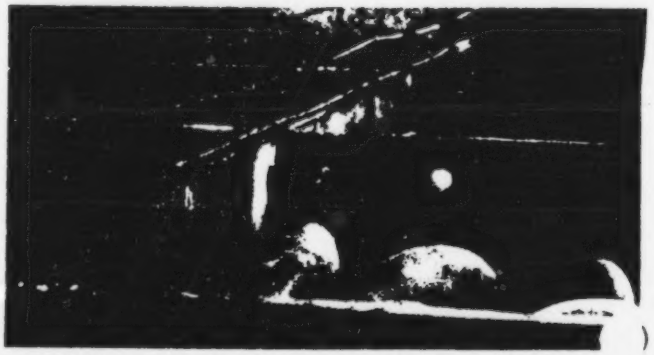
At the upper (warm) end of the thermo-neutral zone, the pig will use several methods to rid itself of unneeded heat released by digestion and physical activity. These methods include:

(1) dilating the blood vessels near the body surface to maximize heat loss,

(2) lying stretched out on cool floors and well separated from pen mates, and

(3) getting the body surface wet by wallowing in the manure area or standing under a sprinkler.

When these methods are insufficient, the pig must reduce feed intake (since the process of digestion inevitably releases



A sprinkler cools pigs by wetting their body surfaces. Moisture evaporates from the skin taking heat from the pigs' bodies.

more heat). This point is called the upper critical temperature. Growth rate and feed conversion are impaired when the pig is kept above its upper critical temperature.

Conditions which affect the upper and lower boundaries of the pig's thermo-neutral zone include more than just air temperature. Relative humidity, air velocity over the pig, the pig's ability to get wet or stay dry, floor type, group size and level of food intake will affect upper or lower critical temperatures.

Choosing the Best Temperature

Productivity of growing pigs is usually unaffected by air temperatures between 15° to 25°C (59° to 77°F) if pigs are:

(1) healthy,
(2) on dry concrete floors,
(3) kept in groups of eight or more per pen,
(4) fed ad-lib (provided with all the feed they will eat)
(5) not exposed to drafts at floor level, and
(6) not exposed to drastic temperature fluctuations (not more than 4°C (7°F) in winter or more than 10°C (18°F) in summer through daily cycles.

A change in any of these conditions narrows the pig's acceptable air temperature range.

A pig's comfort can not be judged by thermometers alone. Observing pig behavior is also necessary. If most pigs are lying comfortably in the resting area and making use of the correct dunging area, barn temperatures are probably satisfactory.

Comfortable pigs lie stretched out on their sides and somewhat separated from pen mates. On the other hand, uncomfortable pigs:

(1) develop wrong dunging patterns,
(2) lie in the dunging area,
(3) lie only huddled in groups,
(4) huddle along walls and pen partitions, and
(5) lie predominantly erect on their sternum rather than stretched out on their sides.

If pigs become restless, irritable or otherwise uncomfortable during periods of frequent ventilation changes, rapid temperature fluctuations may be occurring. Cannibalism outbreaks have been triggered by such conditions. Whenever pigs seem uncomfortable, investigate and make any necessary changes as soon as possible to prevent problems.

The Ventilation Rate

The optimum ventilation rate is determined by finding the best compromise between the need to remove water vapor and other airborne contaminants and the cost of supplementary heat. Determining a ventilation rate, therefore, should begin with establishing a maximum allowable concentration for each airborne contaminant. However, this is difficult.

If the production rates of the various barn contaminants could be accurately predicted, determining ventilation rates could be an exact and precise mathematical problem. Unfortunately, this prediction is not possible. As a result, based largely on trial and error, engineers have arrived at a set of recommended ventilation rates for the average barn, as shown in Table 4.

Learn to recognize uncomfortable pigs. Observe where and how pigs lie; are they huddled together along pen partitions, lying on their sternum or sleeping in the dunging area?

Comfortable pigs lie stretched out on their sides, somewhat separated from pen mates. Strive to make sure that most pigs lie comfortably in the resting area.

Ventilation rates differ with each season. However, the minimum and maximum ventilation rates are the prime concern when designing the feeder barn ventilation system.

During cold weather, the need to remove moisture (a contaminant) will determine the minimum ventilation rate. Warm moist air is continually exhausted and replaced with fresh air. The incoming fresh air absorbs moisture which is later carried out of the barn with exhausted air. Whenever outside air temperatures are below −15° to −18°C (+5° to 0°F), some supplemental heat is desirable. Ventilation which provides acceptable moisture removal will usually also provide sufficient dilution and removal of other airborne contaminants.

How Humidity Affects Ventilation Rate

To fully grasp the importance of ventilation and determining a suitable ventilation rate, an understanding of how humidity affects the ventilation rate is needed.

The amount of water vapor in air is often described by a property called relative humidity (RH). RH is the ratio of the amount of water held in a unit of air to the maximum amount of water the unit of air can hold. For example, when RH is 50%, the air contains one-half of its maximum amount of water.

As air temperature increases, its moisture holding capacity increases. Conversely, when air temperature decreases, moisture capacity decreases. One kg of air containing 10 g of water at 20°C (68°F) has a RH of 70%. Warming the same kg of air to 25°C (77°F) will reduce its RH to 50%. Cooling the air to 15°C (59°F) will increase its RH to 90%.

When a barn is too wet (RH too high), the barn can be made drier (the RH lowered) in one of two ways:

(1) by adding more supplementary heat to make the barn warmer, or

(2) by adding more supplementary heat, but keeping the barn temperature constant by increasing ventilation rate.

Increasing ventilation without adding heat will not make the barn dryer. It will make the barn colder and may increase the RH.

An Interconnected System

The minimum continuous ventilation rate given in Table 4 is exactly that, a minimum. If the barn air smells too strong or is too damp, increase the ventilation rate. Plan and build the ventilation system to allow for this adjustment. However, before making adjustments, be aware that ventilation rate, barn temperature and supplementary heating requirements are all interconnected. Any change in ventilation rate will alter barn temperature and/or heating costs. Every producer must, in consultation with a herd health veterinarian, arrive at a compromise between an acceptable clean and dry airspace and reasonable heating costs.

The heat balance for a typical feeder barn is illustrated in Figure 14. The barn requires supplementary heat in addition to the heat produced by the pigs to maintain a constant temperature at minimum ventilation. Notice that if the ventilation rate was increased by 25%, the ventilation heat loss would increase 25%, but the supplemental heat required would almost double. Without adding supplementary heat it is impossible to increase minimum ventilation and keep barn temperatures constant.

In summer, no amount of ventilation can reduce barn temperature below outside temperature. The maximum summer ventilation rate is determined by the criteria that barn temperature should not rise more than 3°C (5°F) above outside air temperature. The recommended maximum rates in Table 4 will meet this criteria.

Plan for the ventilation system to provide a gradual transition between minimum and maximum ventilation rates. Appropriate fan and control systems are discussed in the next section.

Components of a Good System

The functions required of a good ventilation and heating system and the system components primarily responsible for these functions are shown below.

(1) Air inlets distribute the fresh air uniformly to all animals without causing drafts.

(2) Fans supply enough fresh air to: a) dilute all contaminants to acceptable levels at minimum ventilation and, b) to remove heat at maximum ventilation.

(3) The heating system should supply just enough heat to maintain a comfortable temperature for the pigs without having to reduce ventilation.

(4) The control system provides consistent and coordinated control of heating and ventilation equipment through all four seasons.

(5) Monitors keep the operator informed about the barn environment and give warnings of extremes.

A Word About Fresh Air Inlets

Poorly designed and positioned air inlets and inadequate air distribution systems are responsible for more ventilation

TABLE 4

Ventilation and Heating Recommendations

Type of Barn	Stepped Total Ventilation Rates (per pig)								Supplementary Heat** (watts per pig)			
	STEP 1*		STEP 2		STEP 3		STEP 4		Barn Temp. (°C)	Outside Temp. (°C)		
	L/s	cfm	L/s	cfm	L/s	cfm	L/s	cfm		−20	−30	−34
Continuous Grower-Finisher (20-60 kg)	1.2	2.5	3	6	6	13	22	47	18	5	20	30
Continuous Finisher (60-100 kg)	2.0	4	4	8	8	17	40	85	16	0	25	35
Continuous Grower-Finisher (20-100 kg)	1.5	3	3	6	6	13	30	64	18	5	25	35
All-In-All-Out Grower-Finisher (20-100 kg)	1.2-2.0	2.5-4.0	3	6	6	13	50	106	20	35	50	60

*These are the approximate minimum continuous winter ventilation rates. To accommodate varying barn conditions, minimum ventilation should be manually adjustable from three-quarters to double the recommended rate.

**These values are guidelines only. They are based on a typical building (Figure 2), approximate animal stocking densities and the Step 1 ventilation rates and temperatures shown. Consult an agricultural engineer for information on a particular barn.
1,000 watts = 3,400 BTU/hr.

problems than any other single source. It is pointless to equip a barn with an expensive system of fans and controllers, and not adequately provide for the orderly entry of fresh air into the barn. Perhaps the most important but most difficult to understand concept of ventilation systems is this:

the air inlets, not the fans, dictate where fresh air will go in an airspace.

If a barn is drafty, has stagnant air pockets, or large temperature differences between ends or sides, do not change fan location. Relocate or readjust fresh air inlets.

A well designed, constructed and managed inlet system will:

(1) distribute fresh air uniformly throughout the barn,

(2) admit the fresh air without causing drafts within pens,

(3) cause the fresh air to be thoroughly mixed with room air before reaching the animal space and before being exhausted by fans,

(4) provide control over airflow direction at animal level to encourage proper dunging habits, and

(5) adjust to changing ventilation rates throughout the year.

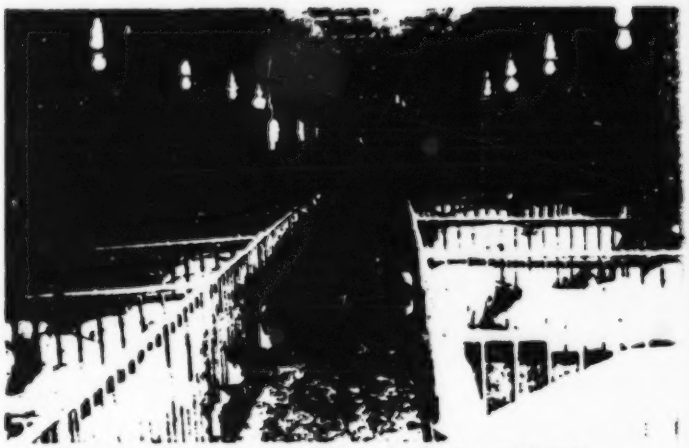
One air inlet system commonly used in swine barns during the past decade consists of a continuous, adjustable polystyrene air inlet baffle mounted at ceiling level below an opening or slot. Fresh air enters the barn through this inlet from the attic. In theory, the inlet baffle is supposed to be adjusted to create a high-speed jet of incoming air moving horizontally across the ceiling. The fresh air mixes with room air before reaching animal level.

However, in practice the continuous air inlet baffle has been difficult to adjust. The main limitation is that with very cold incoming air and low minimum winter ventilation rates, there is just not enough energy, even in a high-speed air jet, to properly mix fresh and stale room air. But these limitations can be overcome with the small modifications described below.

The first modification, designed to make the inlet baffle easier to adjust, consists of placing spacers between the baffle and the ceiling. The spacers can be made of short plywood sections. For winter operation, the baffle is pulled up tight against the spacers. Fresh air enters through the openings between the spacers. Spacers make it easy to adjust the baffle to the small opening needed during winter and ensure that each section of the barn along the air inlet gets the proper amount of fresh air.

However, even in a well constructed barn and with the baffle tightly closed for winter, enough air leaks through doors and fan shutters so that a high-speed air jet can not be achieved. An acceptable solution is to suspend a perforated plastic or plywood duct under, or beside and below the inlet. A fan is attached to the duct to recirculate room air. No attempt is made to develop a high-speed inlet jet. Instead, the baffle is closed up against the spacers, leaving properly spaced gaps to allow cold air to enter more easily than through unplanned cracks.

Cold air (entering through the inlet) that would normally fall toward the floor immediately upon entering the room is intercepted by the warm recirculated barn air and carried



At cold temperatures, air often falls to the floor immediately after it enters this inlet.

Using spacers makes air inlet baffle adjustment more precise and reduces total inlet opening, resulting in a higher negative static pressure in the barn and better control of the incoming air velocity.

Even with a good inlet, air patterns can be unstable. A recirculation tube beneath the air inlet will control and stabilize the flow pattern of incoming air.

When building a new barn it is possible to combine discontinuous air inlets and a recirculation system. This type of integrated air inlet and recirculation system can be precisely designed, is permanent and effective.

out across the ceiling. The recirculation duct allows control over cold air direction and supplies the energy needed to properly mix fresh and room air. A recirculation duct also makes it easier to maintain a uniform temperature throughout the airspace.

In many barns, producers are now installing integrated air inlet recirculation sytems. Contact an agricultural engineer to plan and design the inlet and air recirculation system which best suits your needs. In the average barn, the air inlet system can be expected to cost as much as the fans and their controls. Since air inlets are important in achieving proper ventilation, this is a worthwhile expense.

Choosing Exhaust Fans

A system of staged fans is considered best for swine feeder barns. Usually one or more small fans operate continuously during the winter to provide minimum ventilation. The second set of thermostatically controlled fans (stage two) is large enough to double the ventilation when barn temperature rises and after supplemental heaters are switched off. The third set of thermostatically controlled fans will double ventilation again when the stage two fans can not keep the barn temperature below the set temperature. Lastly, a fourth set of thermostatically controlled fans provide, in total with all the other fans, the required maximum summer ventilation.

Proper sizing of all fan stages is very important. If a feeder barn is ventilated with fewer stages than outlined above, or if the steps between stages are too large, especially with the stage-two fans, very rapid temperature changes may occur as the fans repeatedly turn on and off. Likewise, over-sizing the heating system will cause rapid temperature cycling. If rapid temperature changes occur, some of the heat or fan stages are probably too large.

Minimum ventilation must be maintained at all times to continuously provide fresh air and keep moist barn air from flowing into the air inlet system. However, the minimum ventilation rate should be adjustable to allow the operator to precisely control barn conditions. Changes to the minimum continuous ventilation rate are needed if the barn becomes too damp and humid, the ammonia concentration in the air rises, or a greater or lesser number of animals is housed in the barn. Two simple ways to make the minimum ventilation rate adjustable are to use:

(1) a multi-speed fan with a manual speed control; or

(2) a pair of fans, one of which operates continuously and the other intermittently on a manually adjustable cycle timer.

The range of adjustment should be from three quarters to double the recommended minimum ventilation rate. Two mistakes that are often made by producers are:

(1) controlling the minimum ventilation with a thermostat, and

(2) operating variable speed fans at slow speed for minimum ventilation.

Therefore, avoid these two problems which can reduce the overall effectiveness of the system.

Minimum ventilation must be provided regardless of temperature. If minimum winter fans are controlled by a thermostat, the fans may shut off during cold weather causing the barn to become wet and smelly. Pig performance will suffer. Instead, add supplemental heat so that the barn can be maintained at the desired temperature without reducing the ventilation rate below the minimum level. In the absence of enough heater capacity to maintain the desired barn temperature, it is better to let the temperature fall for a short time, especially during the night, than to reduce the ventilation rate below the minimum.

Variable speed fans operating on variable speed or multi-speed controllers generally do not provide a consistent minimum ventilation rate. The amount of air delivered by these fans when operating below 50% of full-rated speed is subject to major fluctuations due to changing windspeed and wind direction. The result will either be a waste of heat, since the ventilation rate is too high, or an unhealthy environment because the ventilation rate is too low. A further problem with variable speed controllers is that they are difficult to set at a precise speed between 30 and 70% of full-rated speed because small changes in the control setting produce disproportionately large fan speed changes. Variable speed fans can provide the minimum winter ventilation, provided they are not operated at less than 75% of full speed.

The location of exhaust fans within a building is not particularly important to uniform air distribution. Step back just a short distance from the face of an exhaust fan and notice the absence of any air movement. Barn air approaches a fan from all directions and only when very close to the fan is the air forced to speed up to pass through the fan opening.

The location and adjustment of the air inlet system have the main influence on where fresh incoming air will go within

an airspace. In the winter, the ventilation provided by a single exhaust fan in the center of one wall will be as good as that provided by several smaller or slower-running fans spaced along several building walls. Summer ventilation fans should be spaced so that the distance between adjacent fans is not more than twice the width of the barn. Otherwise, air in pens close to the fans may become warm and stale.

Supplementary Heat

Supplemental heat is needed in hog barns to allow proper ventilation system performance whenever the outside temperature falls below approximately −20°C (−4°F). However, since this happens infrequently, many feeder barns operate without supplemental heat. Instead, the ventilation rate is reduced for a few hours and the barn becomes cooler and more humid. Providing the pigs are healthy and their compromised environmental conditions do not persist too long, productivity and health will not be seriously affected. However, if animal health or barn conditions were unsatisfactory before the onset of a cold period, then health and productivity will suffer.

Therefore, adding supplemental heat to a feeder barn is good insurance and allows more flexibility in maintaining the proper barn environment despite the weather. Also note that barns using the all-in-all-out system must have supplemental heat if pigs under 50 kg (110 lb) are to be reared during winter.

Supplemental heat also pays off during periods when temporary problems arise. For example, when a disease outbreak occurs, a warmer barn is needed regardless of outside temperature. Without supplemental heat a warmer barn can not be provided unless ventilation is reduced. Also, if wrong dunging patterns develop, moisture production rates increase markedly. Supplemental heat will allow the producer to increase ventilation until pig dunging patterns are back to normal. Table 4, which lists ventilation recommendations, also gives suggested supplemental heating levels. Supplemental heat is usually provided with electric unit heaters, hot water piping or floor heat.

Air-to-air heat exchangers are useful in feeder barns and can completely remove the need for any other type of heating equipment. It is important to remember that heat exchangers are nothing more than an exhaust fan, an air inlet and a heat source and, therefore, must economically replace the equivalent components of the ventilation system.

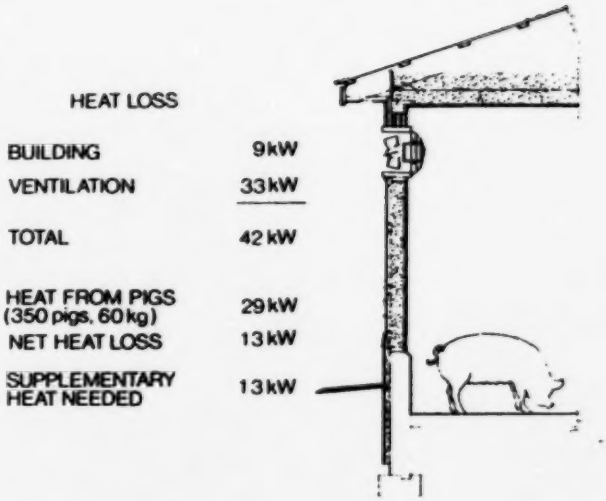


FIGURE 14: *The balance between building and ventilation heat losses and heat produced by pigs dictates the need for supplementary heat.*

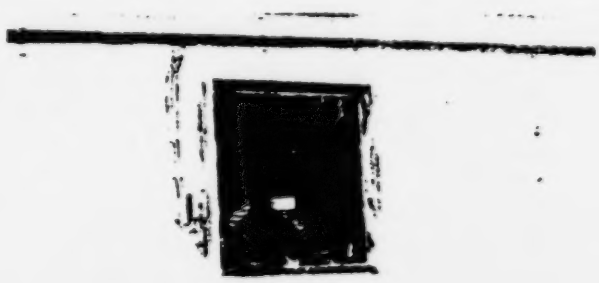
Heat exchangers must be properly controlled and integrated into the total barn ventilation system. Producers should be particularly aware of the potential for drafts with these units. The tempered air from heat exchangers should be directed into a proper air inlet or distribution system. Routine cleaning of heat exchangers is also a must.

The Right Controls...

Since ventilation and heating requirements vary continuously, the barn operator can not manually provide all the adjustments to fans and heaters that are needed. A simple set of controls will regulate fans and heaters to automatically maintain desired room temperature.

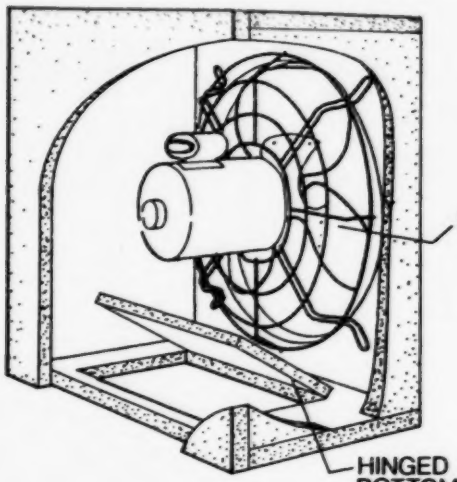
With the staged heating and fan system discussed previously, a minimal control system should consist of the following thermostats.

(1) A heating/cooling thermostat. This is a two-stage thermostat, sometimes sold as a two-speed fan controller with



Summer fans should be fitted with interior covers to seal them off from the barn.

BACK-DRAFT DAMPER



Hinge made of fabric, glue to baffle and damper box.

POLYSTYRENE CONSTRUCTION
USE LATEX-BASED CONTACT CEMENT
FASTEN TO WALL WITH RUBBER TARP STRAPS
TO BE REMOVED FOR THE SUMMER MONTHS

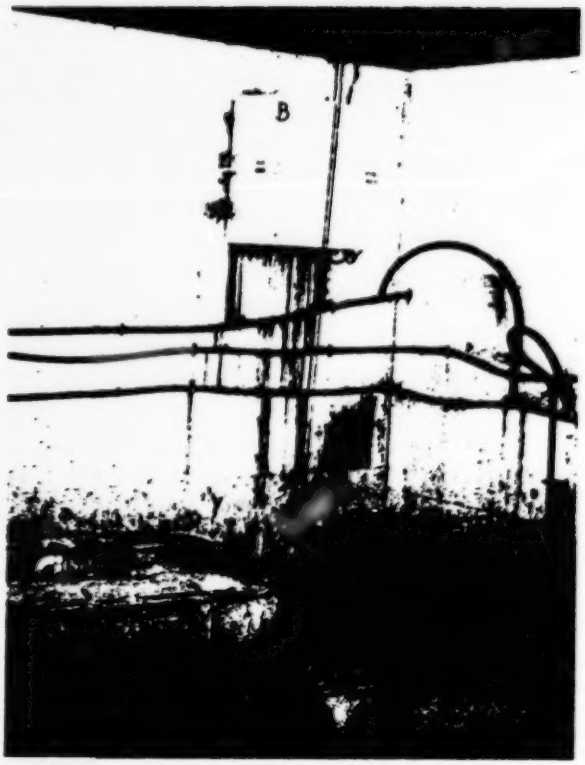
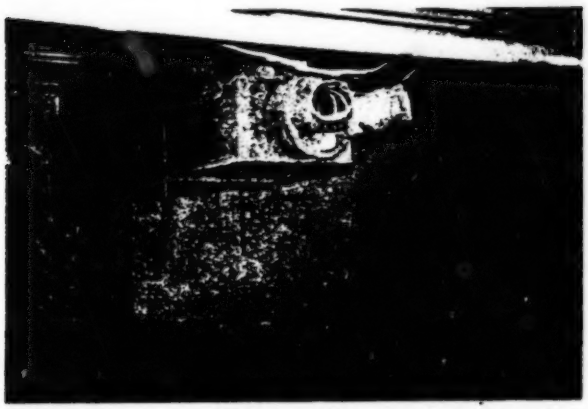


FIGURE 15: *A temporary winter backdraft damper, fitted over an intermittently operated fan, eliminates air leakage, but lets the fan come on automatically.*

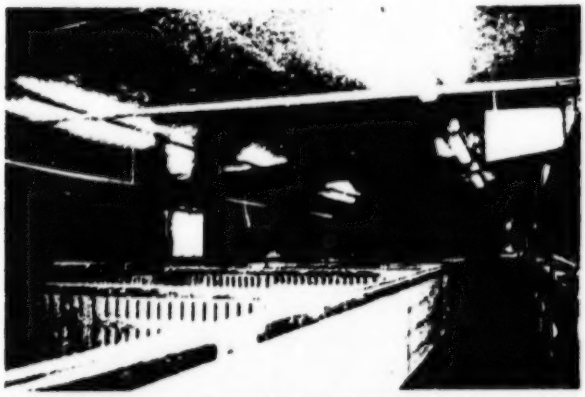
Hot water heating systems are often practical for feeder barns. They warm and cool slowly, moderating temperature changes in the barn.

Warm water circulating through plastic pipes in the floor beneath the sleeping area can provide all the heat needed in a feeder barn and encourages pigs to adopt correct pen behavior.

In an all-in-all-out barn, heat is essential. It is impossible to properly ventilate without heat when a barn is stocked entirely with pigs weighing 20 to 30 kg.



Heat exchangers are another supplementary heat alternative. If a heat exchanger is durable and does not demand excessive labor for cleaning and maintenance, it can be economic.



A heat exchanger is a portion of the ventilation system. Fresh air supplied by this heat exchanger is ducted to the recirculation fan so that it can be mixed and distributed throughout the barn.,

two switches. If barn temperature rises above the set temperature, the second-stage ventilation fans are turned on. If the barn temperature falls below the set-point, fans turn off and the heating system is turned on. There is usually a temperature differential of a few degrees between when the fans turn off and the heater turns on. This control assures that the heat will never be on when the ventilation rate is above the minimum.

(2) A cooling thermostat. This is a single-stage thermostat that will turn the third-stage fans on and off. The thermostat must be set 2°C (3.6°F) above the set temperature of the heating/cooling thermostat so that the third-stage fans do not come on unless the second-stage fans are already operating.

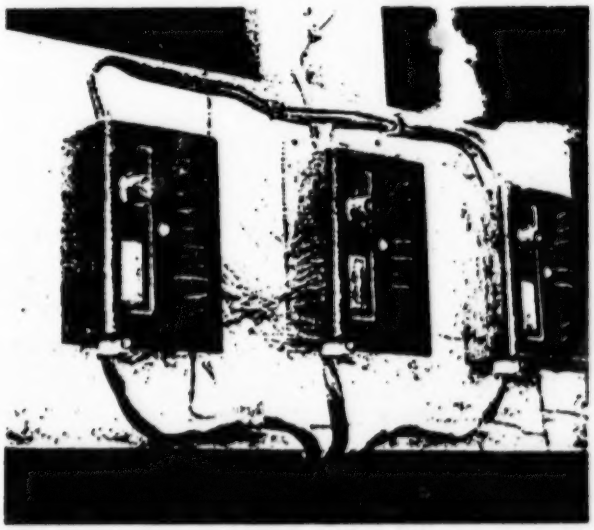
(3) The summer thermostats. These are single-stage thermostats that will turn summer fans on and off. The thermostats must be set 2°C above the set temperature of the cooling thermostat so that the summer fans do not come on unless the second and third-stage fans are already on.

With this simple system of controls, the operator only needs to use three thermostat settings. Even if more than one thermostat controls the summer fans, the settings of the summer thermostats can be the same. Note that the dials on commercial thermostats are not always accurate and, therefore, it is a good idea to use a common thermometer to check that the thermostats are properly sequenced and calibrated.

...And Monitors

Monitors are required in swine feeder barns for two reasons.

(1) To issue alarms. With tightly constructed barns, a failure of the ventilation system can result in over-heating and suffocation of pigs in a very short time. Over-cooling of the barn because of heater failure or controller malfunction is not as likely, but should also be guarded against. A minimal alarm system consists of two thermostats connected to a bell or buzzer in the operator's



Thermostats must be located so that they can sense the temperature of the animal space. Do not put them in a fresh air draft or in an area too sheltered.

house. One thermostat triggers the alarm if barn temperature exceeds an upper limit while the other thermostat sounds the alarm if barn temperature drops below a lower limit. The limits need to be set far enough apart to minimize nuisance triggering of the alarm, but yet close enough to give the operator adequate warning of an impending problem.

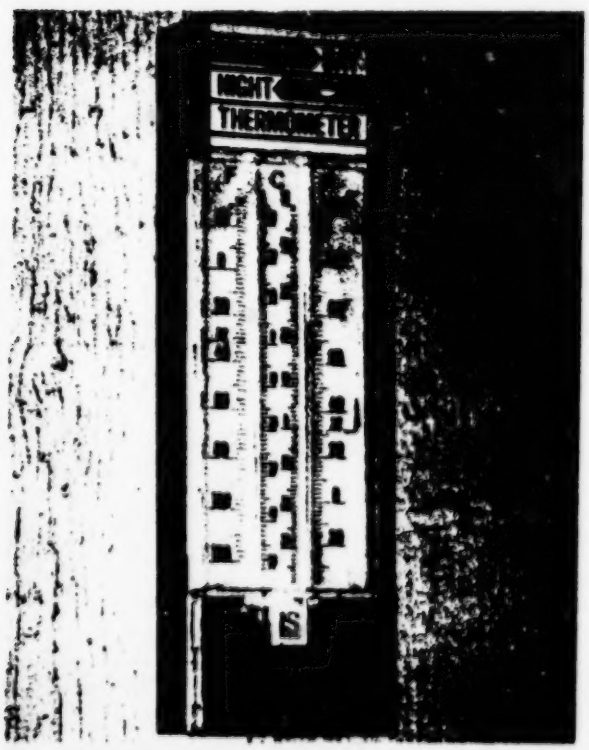
(2) To provide feedback on ventilation system performance. At the very least, there should be a good reference thermometer in every feeder barn to check the operation of the thermostats. In addition, a maximum-minimum thermometer is needed to "record" barn temperature extremes. The reference thermometer should be read every day at approximately the same time. Temperatures should be recorded on paper, at least occasionally, as a permanent record of the performance of the heating and ventilation system. The record can be especially useful for diagnosing problems. Recording barn temperatures also is a good way to evaluate whether the system is achieving objectives set by the operator. The operator must still interpret the pig's behavior to determine whether barn temperature is properly set, rather than just relying on a thermometer.

In addition to a thermometer to measure temperature, operators should purchase an inexpensive hygrometer for measuring humidity. While this instrument can not be left in a barn, it can be used periodically to check that relative humidity (RH) is within the 50 to 80% range. The formation of condensation was once thought to be a good indicator of a high RH. However, with well insulated barns and well mixed airspaces, condensation may not begin to appear until the RH is above 90% which is too high for pigs.

One other useful monitor for managing ventilation systems is a static pressure indicator. A manometer is a simple device that will enable the operator to adjust air inlets to control ventilation. Static pressure should be kept between 15 to 30 Pa (0.06 to 0.12 in of water column).

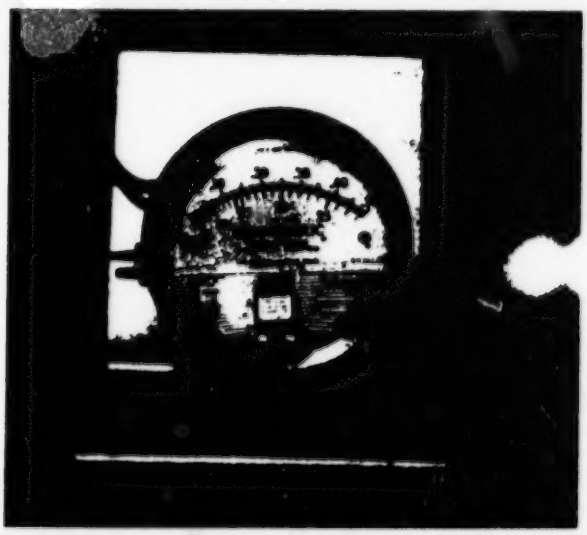
Summary

Section 1 of this manual suggests that the key to successful operation of a feeder barn is its proper design and construction. Although this is true, even the best designed barn can not function properly without a good ventilation system. Pig health and productivity are influenced by how well the barn is ventilated. A ventilation system must incorporate the right combinations of inlets, fans, controls and heating. Each of these factors must be carefully considered.



Use maximum-minimum thermometers to monitor barn temperature. They are widely available, inexpensive and easy to use. Make a habit of reading and resetting them at the same time each day.

This device is a recording hygro-thermograph and plots a continuous record of temperature and relative humidity on a chart. It is very helpful when investigating problems related to environmental control.



A manometer monitors air inlet settings. It indicates the negative static pressure in the barn.

GROWTH PROMOTION - WHAT'S IN STORE

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Summary

Introduction

Maximizing growth rate in the pig has long been an objective of pork producers. From the 1950's, when the growth promoting effects of antibiotics were first discovered, feed additives have become a multi-million dollar business.

Biotechnology promises to bring new products to the marketplace, providing pork producers with even more options for stimulating growth in the pig. Conventional products will no doubt retain a place in the over-all scheme of things, but the investment of 100's of millions of dollars in newer generation growth

promotants by large pharmaceutical companies demonstrates what at least some people suspect their potential impact will be on our industry.

It is important that a discussion on growth promotants acknowledges the many factors involved in their evaluation. Not only must they achieve their primary objective, that is to stimulate faster growth in the pig, but they must do so economically, with no health risk to the animal, stockman or consumer and they must also be acceptable to that consumer.

Growth in the Pig

Before talking about the new generation of growth promotants, it is important for us all to understand a little bit about the growth process itself. The pig, like all animals, is made up of millions of cells; there are different types of cells to perform specific functions, like bone, muscle, liver, brain, etc. They are specialized to do their individual job, so that the health and function of the overall organism - the pig - is maintained. These cells are guided in their daily activity by various signals; one of these is hormones.

Hormones circulate in the blood, travelling from the organs that manufacture them to the cells that accept their signal. Certain kinds of hormones, called peptide, or protein, hormones attach to the surface of cells to send their message inside. Only certain cells accept the message, because the surface of cells contains specific hormone receptors. If Hormone A tries to bind to a receptor designed for Hormone B, it will be rejected. In the same way that only a Robertson screw-driver can drive a Robertson screw, hormones and hormone receptors must be compatible. This helps to provide some of the unique function to individual cell types in the body.

The presence of surface receptors is important, because another type of hormone actually enters the cell to get its message across. These are steroid hormones and they act very differently from the peptide hormones. In past years, steroid-like hormones have been used for growth promotion; an example would be DES. It is an estrogen that functions inside the body like other steroid hormones. The use of steroid-like hormones has been controversial due to associated health concerns. Indeed, DES has been banned from use in this country.

Two new products that may be licenced for use in swine within the next few years are peptide hormones. These are believed to be safer than steroid hormones, because they are less resistant to digestion. Structurally, peptide hormones are very much like dietary protein and are broken down by the digestive enzymes in the gut. Therefore, it is important to understand the difference between steroid hormones and peptide hormones, because of this different degree of degradation in the gut.

Cells respond to circulating hormone messages by either increasing or decreasing some metabolic function. This is important because growth of cells is actually the combination of two events inside the cell - synthesis and breakdown. If the rate of synthesis is greater than the rate of breakdown, then the cell will get larger and growth occurs. Conversely, if the rate of breakdown exceeds that of formation, then the cell will become smaller and the animal will lose weight. Most people are surprised to learn that even in adults, where no net growth occurs (i.e. mature body size has been reached), these processes of formation and degradation continue. In this case, the rate of synthesis balances the rate of degradation, so no net change in size occurs.

Some of the new growth promotants appear to act by altering the rate at which synthesis and degradation occurs in muscle and fat tissue. They are called nutrient repartitioning agents, because they appear to direct nutrient utilization away from undesirable fat synthesis and towards more desirable activities such as growth or milk production.

Muscle growth is much more desirable than fat growth for a number of reasons. First, it is more efficient. Muscle contains a large proportion of water, while fat does not. Thus, fewer nutrients are required to produce a pound of muscle compared to fat. Fat is a concentrated energy storage compound. Therefore, unlike muscle, production of fat requires a lot of nutrients. Second, pork producers are in the business of producing lean tissue. Pigs have not been used for lard for decades. Therefore, more muscle in a pig means more saleable product.

However, there is mounting controversy about how lean an animal carcass should be. Research from Great Britain has demonstrated that excessively lean carcasses tend to have lower quality fat (softer). This is an area which clearly requires detailed study.

Beta-Agonist

Beta-agonists, or B-agonists are a relatively new type of growth promotant that are currently being agressively studied by a number of drug companies. They derive their name from their mode of action. They are not structurally identical to a hormone, but they are close enough that they can mimic their effects. For this reason, they are called "agonists." The term Beta refers to the type of cell surface receptor activated. These receptors are categorized as being either "alpha" or "beta." The B-agonists currently under investigation mimic the effect of the "fight or flight" hormone, known as adrenaline. It is expected that one or more of these compounds will become available in the early 1990's. Possible candidates include cimaterol, clenbuterol and ractopamine.

It seems that the B-agonists act on fat cells to increase degradation and decrease synthesis. In muscle cells, the effect is less clear. They appear to slow the rate of breakdown, but it is unclear if they stimulate the rate of synthesis. In any event, pigs fed these compounds produce leaner carcasses, with more muscling. Feed efficiency is generally improved as well.

Table 1 illustrates the results of one experiment in which the B-agonist clenbuterol was fed at 4 levels to barrows and gilts from 60 to 105 kg. Growth rate is generally unaffected, except at high levels of supplementation. Feed intake is reduced, so feed efficiency is improved. Generally, backfat is reduced in a more or less dose-responsive manner; increases in muscling also tend to rise as the amount of B-agonist increases.

Table 2 also summarizes the response of finishing pigs (62 to 97 kg) to cimaterol. This research, from Kentucky, suggests that the response may not be as great if the product is withdrawn prior to slaughter.

One of the benefits of B-agonists is that they can be offered to the animals in the diet. Other products, to be discussed next, require injection or vaccination.

Somatotropin

Porcine (meaning pig) somatotropin, sometimes called PST or growth hormone, has generated a great deal of interest in both the swine and dairy industries, as a result of observed improvements in productivity. The name has been changed from growth hormone to somatotropin in an attempt to distance the product from the bad publicity associated with steroid hormones in recent years. Whether the name change deflects controversy remains to be seen.

Somatotropin has had a marked effect on carcass quality and performance, as shown in Table 3. Growth rate was increased by 12 to 19 percent, equivalent to about a week and a half less time in the barn, assuming the product is administered from 50 kg to market. Feed efficiency was improved by an average of 25 percent, equivalent to about 40 to 50 kg less feed per pig. Improvements in backfat thickness and loin eye area were similarly impressive.

However, there are a few question marks which remain. In all of the studies reported to date, the pigs were <u>individually</u> injected on a <u>daily</u> basis with the somatotropin. Clearly, this is not practical in a commerical setting and the 5-6 companies who are hoping to market the product are involved in very private studies to develop more practical means of administering the product. There appears to be considerable optimism however. For example, International Minerals and Chemicals, through its subsidiary Pitman-Moore, have announced construction of a $50 million plant to manufacture PST. The press note stated that completion of the

plant was scheduled to coincide with anticipated FDA clearance (US) in 1989. It would appear that the next few years will be an interesting one for those of is in the pork business!

Somatostatin

The regulation of body metabolism is in part controlled by hormones, as mentioned previously. If this system is to work, there must be a very elegant series of checks and counter-checks to ensure that a proper balance is maintained. Somatotropin stimulates growth of the body mass. To prevent excessive growth, other hormones "feed back" onto somatotropin to keep it in control. One of these feedback hormones is called somatostatin; as its name implies, its effect is to stop growth, by inhibiting the release of somatotropin.

Research at the Prairie Swine Centre is now underway to evaluate the effect of immunizing the pig against its own somatostatin. This would have the effect of reducing this hormone and allowing the body to release greater quantities of growth hormone. Therefore, rather than manufacture and supply exogenous PST, let the pig produce its own. Work with sheep has been most encouraging as has the early studies with pigs (Table 4). The lack of effect on feed conversion is not surprising given that weanling pigs are not depositing large fat reserves. The benefit of partitioning nutrients away from this activity would therefore be absent. Perhaps the greatest advantage of this approach is that only 2 or perhaps 3 vaccinations are required, rather than the daily injections described above. Further research, by Drs. Thacker, Laarveld and Kirkwood, are underway in this very exciting area.

Conventional Growth Promotants

The excitement generated by "new" products runs the risk of ignoring existing opportunities. Plenty of research has been carried out with respect to the use of copper and antibiotics to improve rate and efficiency of growth in swine.

However, the movement to minimum disease commercial herds has prompted many managers and veterinarians to question the benefit or the advisability of using antibiotics for growth promotion when disease challenge is maintained at a low level. The removal of at least some of the disease challenge would be expected to reduce the value of growth promotants in these high health herds. Indeed, it has long been recognized that the response of pigs to conventional growth promotants is increased under sub-optimal environmental circumstances.

The Prairie Swine Centre is currently running an experiment to determine if the response to growth promotants would be economical in its own feeding program. Since the Centre opened in

1981, antibiotics have intentionally been eliminated from all diets, and disease problems have been dealt with on an individual basis. The herd has a high health status; continuous post mortem monitoring, blood tests and slaughter checks indicate that the herd is free of the common swine diseases. However, scouring post weaning is a minor problem from time to time.

In this experiment, pigs are weaned at an average 28 days and immediately placed on the experiment. Pigs from different litters are mixed between the two treatments to eliminate litter effects. The experiment lasts 26 days, with weighings on days 5, 12, 19 and 26. Body weight, feed intake and treatment for scours are recorded for all pens on test. In total, 12 pens will receive a commercial pig starter (Co-op Feeds HND Start) with or without Tylazone-240. Preliminary results of this experiment, representing 6 pens (48 pigs) per treatment are summarized in Table 5.

The economics of the two feeding regimes will be evaluated at the end of the experiment. However, it is already clear that from a purely financial perspective, the use of an in-feed antibiotic is still justified. The total experiment will be completed on February 8, 1988. A complete report of the results will follow soon after.

Organic Acids

I would be remiss if I did not discuss the use of organic acids in the diets of young pigs. Originally, these were added to pig feeds, especially those containing high-moisture grains, as a preservative. More recently, they have been added to dry diets, with the objective of improving rate and efficiency of growth. Various studies have evaluated fumaric, citric or propionic acids alone or in combination with copper sulphate and antibiotics.

A summary of trials carried out in both the US and Canada appears in Table 6. On average, the organic acids increased growth rate by about 8% and feed efficiency by 10%. After conducting their own studies, and reviewing the work of others, Cromwell and Burnell from Kentucky suggest that organic acids improve growth rate and feed efficiency by 5% and 7% respectively. An East German survey of European research concluded that fumaric acid results in 5% faster growth and 3% better feed efficiency. Organic acids are quite expensive, and depending on the value placed on more rapid growth, these responses would not recover the added feed cost.

It is also interesting to look at the data in Table 6 and consider the performance of the pigs on the control diet. An average growth rate of 314 grams per day (.7 lb) and feed conversion of 1.86 is considerably poorer than the performance of many commerical herds in Manitoba. One might ask the very legitimate question whether the response to added organic acids

would be as great when current performance is already considerably above the control levels reported here.

Proponents of organic acid usage suggest that organic acids might be used in place of antibiotics to reduce concern about the use of medication in animal production. This point may be legitimate, but animals respond more consistently and to a much greater degree to antibiotics than has even been demonstrated with organic acids. Therefore, replacement of antibiotics with organic acids would clearly depress productivity.

It is difficult to categorically dismiss organic acids as too expensive and uneconomical and therefore not recommended for swine diets. The research is inconsistent and not very conclusive. If you wish to try organic acids, you would be wise to carefully consider the economics of your decision and tread carefully.

Probiotics

Probiotics is a term first used in 1974 to describe products designed to improve the "intestinal microflora" of humans and animals. The concept goes back to the early part of this century when a man by the name of Metchnikoff suggested that Bulgarians lived longer than other Europeans because they ate yoghurt; he suggested that "bad" microbes in the intestinal tract were displaced by the "good" microbes present in yoghurt. The "good" microbes were of the lactobacillus species. Although lactobacilli continue to be the focus of interest, bacillus subtillus and streptococcus have also been considered in more recent research.

Probiotics may also be used to include not only desirable bacteria, but also desirable yeast, enzymes, moulds and even organic acids.

The response to probiotics in research has been even less definitive than that of organic acids, described above. A survey of 15 starter trials revealed an average growth response of 5% and feed efficiency response of 8%. However, 4 of the 15 trials demonstrated no effect of the microbial feed additive. In grower trials, the results are even less positive, with 5 out of 8 showing no benefit. Typical results are shown in Tables 7 and 8.

Part of the problem with probiotic usage appears to be obtaining a stable product, that can be mixed in the feed and remain viable until consumed. Commercial preparations are notoriously variable in their stability; one study revealed that 2 out of 3 products lost about 40% of their "potency" within 3 weeks of being added to a feed.

I think it is fair to say that until more is known about probiotics, they are a product to avoid. The responsibility

clearly rests on the shoulders of the manufacturers and marketers of these products to separate the "wheat from the chaff" if indeed there is any "wheat" and bring some consistency of response. Developing a product that is economical is perhaps an even greater challenge.

Synthetic Amino Acids

Synthetic amino acids are not really growth promotants, but merely a replacement for protein, such as soybean meal or canola meal in the diet. It is however, appropriate to bring them up at this time because their usage in the swine industry is almost certain to increase.

The major development in this area is the harnessing of bacteria to synthethize synthetic amino acids much more efficiently than in the past, due to the application of some of the tools of biotechnology. Currently, lysine and methionine have been available to the feed industry at reasonable cost. The next major breakthrough will occur when tryptophan and threonine become available at a competitive price. These two amino acids are second limiting in swine diets based on corn and coarse grains, respectively.

Recently, a Japanese company announced their ability to manufacture tryptophan at about one quarter the previous cost! Another synthetic amino acid, phenylalaníne is also dropping in price rapidly.

This development may affect the pork industry in two ways. First, the cost of feed could be reduced. Second, the price of synthetic amino acids, which currently is dictated by the price of protein meals, may soon drop sufficiently that they will then dictate the price of protein supplements. The tables may very well be turned from the present situation; the effect on cropping practices in Manitoba could be notable!

Summary

The next decade holds tremendous promise for the swine industry, due to the development of new growth promoting products. A greater sophistication of the industry is inevitable, due to the likelihood of being able to manipulate product quality much more precisely. The demands placed on the technical ability of pork producers, already rising quickly, will accelerate. Familiarity with the product(s) and an understanding of their application on an individual's farm will be necessary to maintain competitiveness on the one hand, and to avoid costly errors on the other. It is also apparent that if these products become available in other countries, Canada's position as a major exporting nation will require its concurrent participation in the new technologies.

TABLE 1 EFFECT OF CIMATEROL (B-AGONIST) ON THE PERFORMANCE OF SWINE

Observation	Cimaterol (ppm) 0	.05	.20	1.00
No. of pigs	47	46	46	43
Avg. Daily Gain, g	790	789	789	739
Avg. Daily Feed, g	2920	2860	2850	2700
Feed:Gain	3.75	3.62	3.61	3.65
Dressing Percent	74.1	74.1	73.8	74.8
Avg. Backfat, cm	3.20	3.00	3.02	2.90
Loin Eye Area, cm^2	36.9	37.9	38.9	40.2
Percent Carcass Muscle	55.5	56.4	57.0	58.2

Source: Dalrymple & Ingle, 1986

TABLE 2 EFFECT OF WITHDRAWAL ON THE RESPONSE OF PIGS TO CIMATEROL

Cimaterol level, ppm	0	.25	.25	.25	.50
Withdrawal time, days	0	1	3	5	1
No. of pigs	40	40	40	40	40
Avg. Daily Gain, g	770	770	830	812	794
Avg. Daily Feed, g	2854	2763	2913	2868	2840
Feed:Gain	3.74	3.66	3.59	3.57	3.60
Dressing Percent	72.8	73.6	73.7	73.5	73.7
Avg. Backfat, cm	3.51	3.35	3.33	3.35	3.23
Loin Eye Area, cm^2	31.2	33.6	33.7	33.4	34.9
Percent Carcass Muscle	51.6	53.1	53.1	53.1	54.1

Source: Cromwell et al., 1987

TABLE 3 EFFECT OF PORCINE SOMATOTROPIN ON THE PERFORMANCE AND CARCASS QUALITY OF SWINE

Research Site	Percent Improvement[1]			
	Avg. Daily Gain	Feed Conversion	Backfat Thickness	Loin Eye Area
Illinois	+14 (75)	+40 (75)	+58 (113)	+13 (38)
Cornell	+19 (60)	+28 (120)	+33 (200)	+10 (120)
Penn State	+14 (70)	+17 (70)	+25[2] (70)	+17[2] (70)
Monsanto	+12 (33)	+16 (132)	+15 (66)	+18 (132)
Purdue	+3	+19	+21	+25

[1] Percent improvement compared to control pigs. Dose of PST (ug/kg) at which maximal improvement was observed is reported in brackets.

[2] Reported as total carcass lipid and total muscle mass, respectively.

TABLE 4 EFFECT OF SOMATOSTATIN IMMUNIZATION ON THE PERFORMANCE OF WEANLING PIGS

	Somatostatin Dose (ug/day)			
	0	5	25	100
Avg. Daily Gain, g	488	500	558	546
Avg. Daily Feed, g	869	877	939	987
Feed Conversion	1.8	1.7	1.7	1.8

Source: Thacker and Laarveld, 1986

TABLE 5 EFFECT OF MEDICATION IN THE PIG STARTER ON THE PERFORMANCE OF PIGS IN A HIGH HEALTH HERD

	Medicated	Plain[1]	Diff.[2]
No. of Pigs	48	48	
Avg. Initial Wt, kg	8.0	7.9	
Avg. Final Wt, kg	21.1	17.7	3.4 kg
Avg. Daily Gain, g			
Overall	506	374	+35%
0- 5 Days	252	165	+54%
6-12 Days	452	249	+82%
13-19 days	613	426	+44%
20-26 days	652	585	+11%
Avg. Daily Feed, g	764	615	+24%
Feed Conversion	1.51	1.65	+8%
Feed Cost/kg gain, $	.49	.52	+6%
Mortality	0/48	1/48	
Scour Treatments			
-No. Pigs	3/48	13/48	
-Total Cost, $	.83	7.27	

Pigs were weaned at approximately 28 days of age, mixed in pens to eliminate litter effects and immediately started on the experiment. The experiment lasted 26 days, during which feed and water were available ad libitum.

[1] Tylazone 240
[2] Difference, medicated vs plain

TABLE 6 RESPONSE OF WEANLING PIGS TO ORGANIC ACIDS

Research Site		Organic Acid Control	Propionic	Citric	Fumaric
Illinois[1]	ADG*	252	241	264	260
	F:G	1.96	1.82	1.82	1.82
	ADG*	261	-	-	297
	F:G	1.92	-	-	1.67
	ADG*	307	-	-	305
	F:G	1.92	-	-	1.80
Illinois[2]	ADG	359	-	353	-
	F:G	1.74	-	1.63	-
	ADG	246	-	322	-
	F:G	2.07	-	1.81	-
	ADG*	366	-	337	389
	F:G	1.77		1.69	1.70
Alberta[3]	ADG*	407	-	437	426
	F:G	1.61		1.45	1.49

[1] 30-day old weaned pigs on test for 4 weeks. Organic acids added at the rate of 2-4% of the diet.

[2] 28-32-day old weaned pigs on test for 21 days. Organic acids added at the rate of .75% to 1.50% of the diet.

[3] 28-day old weaned pigs on test for 28 days. Organic acids added at the rate of 2% of the diet.

* Control diet contained no antibiotic.

TABLE 7 RESPONSE OF RUNT PIGS TO B. SUBTILLUS

	Control	B. Subtillus
Average Daily Gain, g	330	310
Feed conversion ratio	1.46	1.41

Initial weight of 3.3 kg with pigs on test for 35 days

TABLE 8 EFFECT OF B. SUBTILLUS IN STARTER DIET

	Level of B. Subtillus		
	0	0.1	0.2
Avg. Daily Gain, g	370	330	340
Feed conversion	1.64	1.68	1.71

Initial weight of 5.3 kg with pigs on test for 42 days